MATERIALS & METHODS

THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

METALS & ALLOYS

Lightweight Motors Built of Large Aluminum Die Castings

Stone-Like Plastic Formed by Molding

Aluminum Dipcoated Steel

Vapor Degreasing

The Use of Ultra-Fine Particles in Powder Metallurgy

Extruded Shapes Speed Brass Forging Output

Rectification of High Temperature Salt Baths

Precision Metal Parts Produced by Electroforming

Tool Steels

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MATERIALS & METHODS

THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE
Volume 24, Number 1 July, 1946

The economy and accuracy of punch press products would be much less were it not for the high development of tool steels. This cover scene is from a plant of Westinghouse Electric Corp.

ABP

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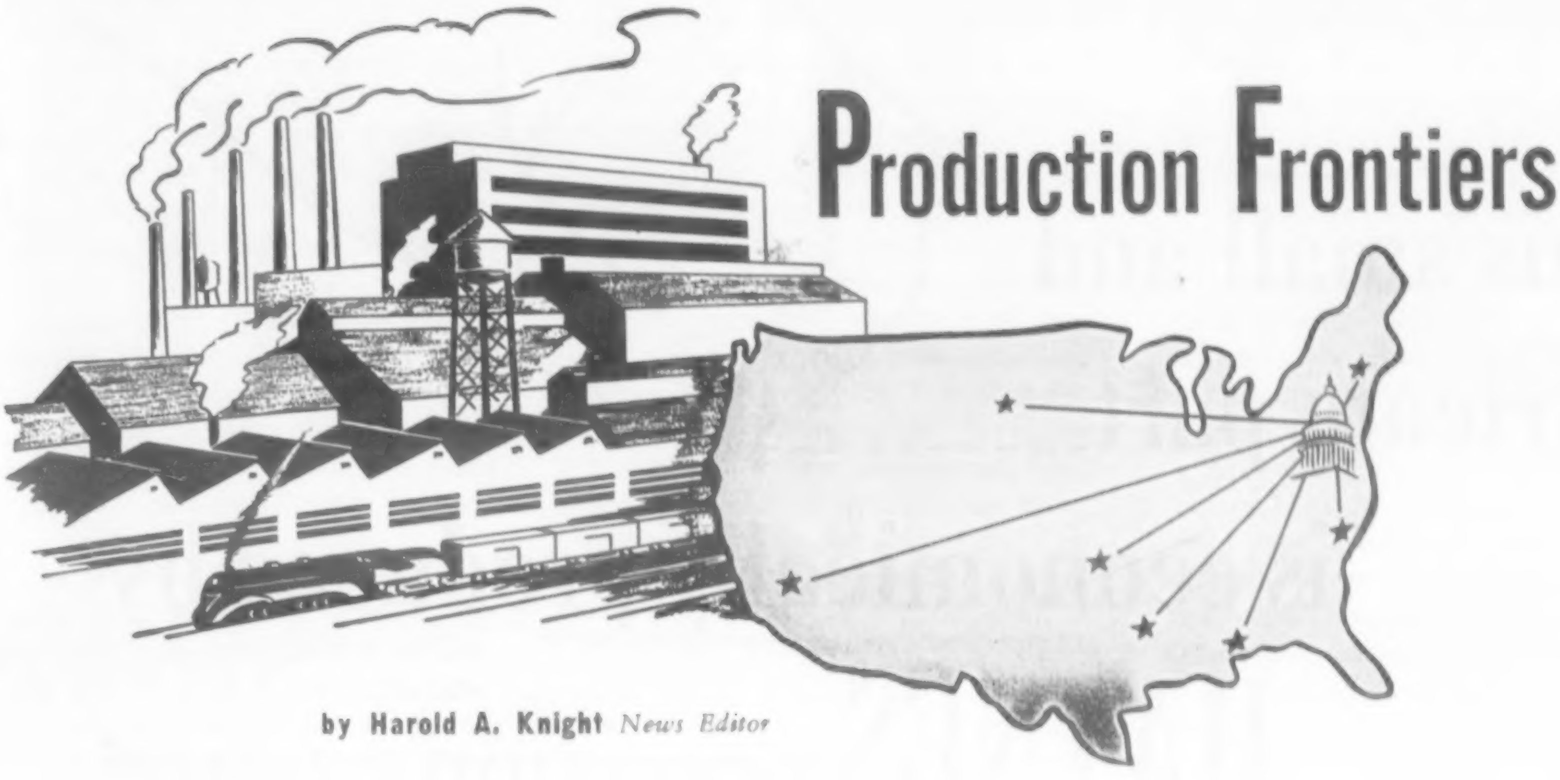
INDUCTION HEATING: "Materials & Methods Manual" No. 18

RP REINHOLD



by **Harold A. Knight** *News Editor*

Buyers' Strike? Customers, Too, Have Their Ceilings

The worm may turn. The buyer may go on strike. King Customer may at last put thumbs down on ever-rising wages and prices. It has happened before and can happen again.

Trying to sound out the keynote of the situation in these columns each month, we go all-out this month on the possibility of a buyers' strike. It is not an original idea. The *Wall Street Journal* has suggested it is in the making. The financial editor of the *N. Y. World-Telegram* has guardedly hinted at such a possibility. "We are on our way to the final squeeze by the customer—for the customer always has his own ceiling price," stated Enders M. Voorhees, chairman of the Finance Committee, U. S. Steel Corp., at the annual meeting of the American Iron & Steel Institute.

We recall a similar inflationary period in the early 1920's after War I. Then, too, the buyers at last went on strike and the price situation changed—literally over night. We awoke one morning and read our usual morning paper at breakfast, eyes popping at a full page advertisement of John Wanamaker—all prices cut 20% immediately. It was the "Shot heard 'round the (mercantile) world." There followed a mad scramble to cut prices, many trying to out-Wanamaker Wanamaker!

Mr. Voorhees told the gathered steel men a lot of cold and grass-roots facts. "The enormous pile of paper claims—hand money, bank deposits, government bonds, etc.—in the hands of our citizens and corporations is not a criterion of prosperity," said he, "for that great pile was accumulated in creating goods and services which were destroyed and hence were never available for exchange against the paper. We do not yet know what that pile of paper will do to our economy."

From which one may again conclude that wars never bring true prosperity and that prosperity can only accrue through creation of much peace-time wealth—high production. We are, in fact, poor when such a typical, basic and important commodity as copper is so scarce.

Strikes in the copper mining, smelting, refining and fabricating industries have badly crippled the billion and a half dollar electrical manufacturing industry, employing 400,000 people—just to mention the industry taking 55% of our copper. Many appliance dealers may be forced into bankruptcy because of no appliances to sell. Housing projects for veterans will be hamstrung for lack of wire, cable and electric building materials. Makers of copper wire and cable were operating at 25 to 75% of capacity in early June, with the situation still deteriorating.

Though the government stockpile of copper is 400,000 tons, only half is electrolytic and not over 100,000 tons in the form fit for cable makers. At the end of May the government held only 1,000 tons in the form of wire bars against a monthly consumption of 60,000 tons. The electrical industry also suffers from shortages of steel, cotton and lead.

Current Thinking at Washington

We wandered down to Washington recently to contact such key departments as the Office of International Trade, the Civilian Production Administration, the Government Administration of the Coal Mines, the Treasury Department, and others. Here are some of the more important and interesting facts we gleaned.

Steel is still one of the scarcest and most critical commodities. However, a top priority has been imposed on 150,000 tons needed sorely for completing the Veterans' housing program, such as soil pipe, radiation, furnaces and nails. Makers of wire nails are cooperating most generously in this despite the fact that for many makers nails are manufactured at a loss under OPA regulations.

Another OPA inconsistency is that the ceilings on hardwood blocks are higher than for hardware flooring cut from those blocks; hence, it is natural

to sell the block and not manufacture the flooring at all. Pig iron is extremely scarce and the situation tough. There is a basic shortage of steel scrap, and it seems likely that battle scrap must be brought back to the United States despite the high cost of sorting, gathering and transportation.

Those who have the Veterans' housing responsibility are confident that the scheduled program will be met despite the many obstacles. They predict that the Veterans will stage riots if the housing situation does not improve soon.

As to peace time production generally, one "higher up" stated: "Up to April 1 we were doing a particularly fine job in production, but since that date things have been pretty bad because of the strikes. However, we're now over the major strike troubles." He went on to say that sooner or later the labor man will realize that wholesale strikes injure the workman himself the very first of all.

As to assuming more responsibility in national affairs and loaning to Great Britain, one summed it up: "The booty and loot we won in this war was world responsibility. We can't allow ourselves to become isolated. Otherwise, the rest of the world will work out things to please themselves—and this may not be to our liking.

As to the British loan, Britain, next to us, is the last democracy, so we've got to help her now. It will give a good impression of a democracy to the rest of the world. Such a loan is an insurance policy. As to collateral for such a loan, "character loans used to be considered the best loans by banks."

Speaking of the recent industrial chaos through strikes, one official stated: "If we can keep the ship of state from rocking another four to six months, we'll have the greatest prosperity the country has ever seen. We must accomplish as much as we can through sensible voluntary action on the part of the people. Regulations breed regulations and priorities breed priorities. Moreover, you can't write good judgment into any law."

Scientists Get the Lollypops

The Russian scientists and engineers have the top grade priorities to the handsome things of life these days. They are awarded extra special rations, clothes, special salaries, new apartments and fine automobiles—many with chauffeurs. In many parts of the country new housing is being earmarked for men of science.

Such is the report of Eddy Gilmore, Associated Press correspondent in Moscow for five years. Always respected in Russia, scientists now have been raised several stations to the top brackets, in a class with marshals, generals and high party functionaries. The Soviet Government is busily building them new laboratories, finding them the equipment they want, and giving them the green light they need. Life for them is like that of

"Hey, Joe! I've done it! A non-metallic metal!!"

Aladdin who rubbed the magic lamp, the friendly genii providing his slightest wish.

Russia has a hard core of scientists to build from, although they are mostly beyond middle age. An energetic campaign is under way to interest young people in science. In a speech at the Kremlin last November, Molotov said that Russia soon would have atomic energy and many other modern scientific and engineering enterprises. "And—one should never underestimate the Russians," states Mr. Gilmore, who goes on to say that Russia must be well behind the United States in development of atomic energy.

He says further that Russia's leaders have no illusions about how far her scientists must progress to catch up with the United States and Britain. They are well aware of and impressed by the excellence and skill of Americans.

Meanwhile, the Soviet press reports that the State Optical Institute, U.S.S.R., built a series of electronic microscopes during 1945, the latest with magnifying power of 50,000, which is five times that of their first microscope of 1940. It allows study of particles equal to 1/10,000,000 of a millimeter. Particles with a diameter of 10 to 20 atoms and sometimes even some of the larger molecules are discernible under this instrument. It is expected to play an important role in the production of high-octane gasoline, synthetic rubber and synthetic fats.

The Metal of "Love and Beauty"

Vanadium, named after Vanadis, the Scandinavian goddess of love and beauty, was first discovered in brown lead ores of Mexico in 1801 by Del Rio, but its existence as an individual element was disputed until 1830 when Sefstrom identified and named it.

Tools made of Swedish ore had outstanding properties, as we still realize by current experience. Sefstrom attributed this superior quality to small amounts of vanadium in the ore. As late as 1892 vanadium was called the world's rarest metal—$4,792 per lb. (against $3 today). Earliest uses were for making aniline black and writing ink.

Professor Arnold, well known metallurgist of Sheffield, England, proved vanadium's value as an alloying agent. Added to plain carbon steel, it increased elastic limits 40 to 100%, boosted tensile strength 10 to 60%, without hurting ductility.

In 1905 an alleged immense deposit of vanadium was found in the Peruvian Andes. A United States party of metallurgists and engineers struggled through the wild, mountainous interior of Peru, only to find low grade ore of little commercial value. With both souls and soles sore, they packed up for the long trek to Pittsburgh, their smoky home, when—lo!—they heard of another discovery not so very far away. This time they struck pay dirt, ranging from 1.35% vanadium for the "broza," a red shale, to 12% in the

pure crystals of a yellow oxide, "pascoite." A typical glamorous mining discovery!

The rich vanadium was on a windswept plateau 15,400 ft. above sea level (Mt. Whitney in California is 14,492 ft. high). The property was sold to the American Vanadium Co. (since 1919, Vanadium Corp. of America).

The site is Mina Ragra, in Western Peru, 250 miles from Lima. At first the nearest railroad was 24½ miles from the mine. The distance from Mina Ragra to Jumasha on Lake Pun Run is 4½ miles down a heavy grade, the last 500 ft. of which is a 45-deg. incline. Those queer woolly beasts, llamas, took the ore from the mine to the reduction plant at Jumasha until 1920, refusing to budge one step if their burden exceeded the quota by a mere ounce. Thereafter, a narrow-gage railroad, running over terrain like that of the "Toonerville trolley," did the transporting.

By water and rail, by lakes and oceans, the concentrated ore finally reaches the Corporation's Bridgeville, Pa. plant, where it is converted to ferrovanadium and other vanadium products. Since 1905 vanadium has been discovered in Colorado and South Africa, but Mina Ragra remains the world's largest single source of the metal. The deposit contains a wide variety of vanadium ores, each of which requires a different metallurgical treatment in the reduction plant.

Native Indians, known as Cholos, make up the majority of the working force. Having spent all of their lives in the thin air of the high Andes, they can work strenuously without tiring. Visitors find every step exertion and often develop mountain sickness. Vanadium, of course, makes steel stronger, more elastic and ductile. Its added strength has made it possible to reduce size and weights of many parts, such as in an automobile. Vanadium is used in catalysts in manufacture of sulphuric acid and phtalic anhydride, in dyes and inks, paints and varnish driers, in insecticides, photography and many other fields.

Because of its high melting point of 3119 F and affinity for oxygen, it is very difficult to produce. It is therefore usually reduced to an alloy consisting of 40% vanadium and 60% iron, which has a melting point of 2600 to 2700 F.

Japan's Steel: Estimated and Factual

During the war there was mystery here as to Japan's tonnage of steel production. In this column of October, 1942 we stated that Japan's steel capacity was under 8,000,000 tons yearly at that time, which perhaps was close enough to facts. Meanwhile, steel capacity and production was probably increasing on that date.

Thus, the final figures for 1943 production for the Japanese Empire, as now reported by the American Iron & Steel Institute, was 9,656,000 net tons. Thereafter, as a result of naval blockade and bombings, it declined steadily.

In 1930, only 2,070,000 tons of steel were made in Japan; in 1934, output was 6,991,000 tons. By 1944 it had fallen to 7,017,000 tons. At the close of 1945, her industry was producing only at the rate of 120,000 tons yearly. During Japan's banner year of 1943 the United States would have produced the equivalent of one year's Jap output in only 38 days.

Incidentally, and shifting to Europe, the Allied Control Council on Jan. 10 decided to limit German steel capacity to 7,500,000 tons yearly, with initial production of 5,800,000 tons annually.

Chit Chat Re This and That

There is one man, formerly high in Washington, who is taking literally the old saw: "Changing swords to plowshares." This is Lt.-Gen. L. H. Campbell, Jr., Chief of Ordnance, who has stopped making swords and has become vice president of International Harvester Co.

Have any of you engineers made exhaustive tests of corkscrews, measuring, for instance, their efficiency in foot-pounds of exerted pull? *Modern Packaging* magazine reports such tests and concludes: "The solid silver ones with the bone handles do not necessarily operate as well as the steel ones with the wooden handles. In fact, the most efficient was among the least expensive."

By the end of 1946 between 75 and 100 million lb. of magnesium will be used annually; while by the end of 1947 annual consumption will be 150 to 200 million lb., predicts T. W. Atkins of the Magnesium Assn.

In discussion of German automotive engineering practice at the June SAE convention, it was pointed out that German practice is poorly adapted to American mass production techniques. Standardization is lacking and many different methods are used to solve similar problems. Germans appear to love gadgets, the German public accepting mechanical features with shortcomings not tolerated here.

Use of ceramic and sintered materials in the production of high heat resisting turbine blades is one of the many noteworthy developments in the German electrical and technical ceramic industry described in a report released by the Office of the Publication Board, Department of Commerce, PB-18776.

There Are "Bugs" in Every Project

Passive courtesy is not enough. There is a story of a railroad passenger who found his berth already occupied by an all-but-invisible intruder, and he wrote a scorching letter of protest against insect-infested cars. By return mail he received so gracious and apologetic a communication that he was ashamed of having made a row about such a trifling matter and he was about to say so in another letter. At this point he came across his original letter which had been included with the company's reply through an oversight. Written across the top of it was this scrawled pencil notation: "Send this crank the bug letter—No. B-274."

—Gleaned from *Railway Age*

Red, Green and Amber

Westinghouse has developed a projector for use on airfields which throws three beams of colored light into the air to guide landing pilots. A green path is followed for a safe landing. Amber denotes that the plane is too high and red means too low.

So, they tell the story of a pilot testing out the projector, who invariably came in too high for a good landing. Finally, crawling out of the cockpit, he disgustedly remarked to himself and the cock-eyed-world in general: "I'm 'Forever Amber'".

News of

Engineers — Companies — Societies

Engineers

Dr. Janet Z. Briggs, for ten years metallurgist with the Crucible Steel Co., has joined the Climax Molybdenum Co. to do technical work . . . *E. W. Schoen* has joined the Bellevue Industrial Furnace Co., Detroit 7, as metallurgical engineer, having been experienced in metallurgical control of steel-making, in design, installation and operation of heat treating equipment and in process and quality control of automotive and aircraft parts . . . *John Alico* has been made director of research and development of the National Magnesium Corp., New York. He is an author of technical books and magazine articles, and a prominent technical society member.

Frank B. Lounsberry, formerly vice president in charge of manufacturing, Allegheny Ludlum Steel Corp., has been elected to the newly created office of vice president in charge of methods and processes. He has had experience with several steel companies . . . *Clifford W. Sponsel* has been appointed general manager of Brooks & Perkins, makers of deep drawn magnesium stampings and assemblies . . . *Harry Costello,* for many years a die casting designer and engineer, has joined the Advance Pressure Castings, Inc., Brooklyn 22, being in charge of the estimating division.

J. L. Klein has been appointed director of research of the Jessop Steel Co., Washington, Pa. He has been a metallurgist, both with Jessop and Crucible Steel Co., and is the author of a paper on hardening of tool steels . . . *Dr. David S. Saxon* has joined the research staff of Philips Laboratories, Inc. as an associate physicist in charge of theoretical physics, having been prominent in radar development at M. I. T. . . . *William C. Schulte* has become quality manager, Curtiss-Wright Corp., Propeller Div., Caldwell, N. J., having previously been in charge of all metallurgy pertaining to inspection.

Howard F. MacMillin, prominent in development and manufacture of hydraulic presses and other machinery, has been made vice president of Bryant Machinery & Engineering Co., Chicago . . . *Frank J. Wood,* formerly with Goodman Mfg. Co., has joined Loewy Construction Co., Inc., as chief engineer of the rolling mill division, following many years of similar experience with several companies . . . *Ralph L. Wilcox* is now assistant factory manager, Detroit plant, Gerity-Michigan Die Casting Co. For 16 years he was with New Jersey Zinc Co. and has served as zinc consultant to the WPB. He has co-authored technical papers.

Frank R. Hicks, released by the Navy, has become assistant metallurgist with the U. S. Spring & Bumper Co., Los Angeles . . . *M. G. Sedam* has been made vice president in charge of research and production of Alloy Rods Co. He has taught welding metallurgy and was prominent in the development of ferritic electrodes for welding armor . . . *Joseph M. Perrone* has been appointed director of research of Watson-Standard Co., Pittsburgh, having for three years researched on protective coatings at Mellon Institute of Industrial Research . . . *R. M. Wilson, Jr.* has joined the technical service section, Development & Research Div., International Nickel Co. at New York as welding engineer, having been welding engineer with General Electric Co.

Harold C. Miller has joined Charles Hardy, Inc., in charge of research and development in powder metallurgy as applied to the electronic industry and is engaged on ferromagnetic powders. He has been with the Ordnance Research Center as major . . . *James A. Clark,* a captain at Watervliet and Watertown arsenals as assistant production superintendent and production metallurgist, has joined the operations staff of the Vanadium Alloys Steel Co. . . . *Robert F. Golden* now heads the new research and development department of the Eaton Mfg. Co. . . . *Kenneth P. Schory,* experienced industrial designer, has joined Product Designers, Chicago.

Companies

The *Aluminum Co. of America* will construct a $30,000,000 plant near Davenport, Iowa, for the rolling of aluminum plate and sheet. It should turn out the widest aluminum sheet in the world.

The *American Brake Shoe Co.* will build a $2,000,000 nonferrous foundry at Meadville, Pa., to produce bronze bearings and castings.

The first commercial shot-peening company on the West Coast has been established, the *Metal Improvement Co.,* 2441 E. Olympic Blvd., Los Angeles 21.

The *O. K. Stamping Corp.* has been organized in Fort Wayne, Ind., to do contract work in metal stamping and production.

The *Barium Steel Corp.* has acquired the *Detroit Steel Casting Co.,* producer of carbon and alloy steel castings, thus giving Barium ten operating subsidiaries in production of steel and other metal products.

The *"H. C. Clauser Foundryette"* has been established at 616 N. Fulton St., Allentown, Pa., by a returned veteran for the manufacture of honorable discharge and other emblems.

The *James F. Lincoln Arc Welding Foundation,* Cleveland, announces a $200,000 "Design-for-Progress" award program, involving 452 awards, and pertaining to design, manufacture or construction of machinery or parts concerned with arc welding.

Dow Chemical Co. has set up a new laboratory in order to greatly expand the metals and cathodic protection research program begun six years ago, with emphasis on magnesium for cathodic protection.

A new plant for the manufacture of carbide cutting tools has been opened at Hawthorne, Calif., by the *Wendt-Sonis Co.,* Hannibal, Mo.

A new company has been formed for the manufacture of industrial coating and finishes, the *Merchants Chemical Co.,* Elm Court, Stamford, Conn.

The *Keystone Abrasive Wheel, Inc.,* Carnegie, Pa., has rebuilt the plant that was destroyed in a $500,000 fire last October.

The *Animal Trap Co. of America,* Lititz, Pa., has bought the Molded Products Div. from the Wm. L. Gilbert Clock Corp., Winsted, Conn.

The *Reynolds Metals Co.* recently leased from the government a large aluminum sheet rolling mill at McCook, Ill., containing 3,000,000 sq. ft.

Societies

The technical committee of the *Drop Forging Assn.* has launched a program of technical research on closed impression die forgings, on comparative data on properties of forged and cast materials, and related subjects . . . The first National Instrument Conference and Exhibit of the *Instrument Society of America* will be held Sept. 16-20 in the William Penn Hotel, Pittsburgh. There will be 15 technical sessions . . . The *American Society of Body Engineers, Inc.* will hold a technical convention Oct. 23-25 in the Rackham Memorial Bldg., Detroit. Suppliers of body materials will exhibit their latest and most advanced ideas on auto bodies.

Meetings and Expositions

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, corrosion conference. Gibson Island, Md. July 15-19, 1946.

INSTITUTE OF THE AERONAUTICAL SCIENCES, summer meeting. Los Angeles, Calif. July 18-19, 1946.

AMERICAN CHEMICAL SOCIETY, semi-annual meeting. Chicago, Ill. Sept. 9-13, 1946.

NATIONAL CHEMICAL EXPOSITION. Chicago, Ill. Sept. 10-14, 1946.

SOCIETY OF AUTOMOTIVE ENGINEERS, national tractor meeting. Milwaukee, Wis. Sept. 11-12, 1946.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, 75th anniversary meeting. New York, N. Y. Sept. 16-18, 1946.

INSTRUMENT SOCIETY OF AMERICA, national instrumentation exhibit and conference. Pittsburgh, Pa. Sept. 16-20, 1946.

AN EDITORIAL

Precision Everywhere

It is commonplace now to comment on the impetus given by the war to precision manufacturing. Editors like ourselves regularly and publicly note the large number of plants and operators formerly awed by 0.001-in. tolerances who are now completely nonchalant about 0.0001-in. Most such prideful observations are concerned with our modern ability to mass-produce parts to ultra-close tolerances primarily by machining. Modern machine tools and controls for the common machining operations, and the introduction of such refinements as superfinishing, microhoning, shaving, precision broaching, etc., have made these most accurate basic production methods even more so. Similarly, advances in stamping, punching and cold heading practice have knocked tenths of thousandths off the already extremely narrow tolerances applicable to these operations.

Equally noteworthy though less frequently noted is the increased precision currently available in other methods of producing parts, particularly in methods not normally considered as high-precision processes, and in metal working operations that are of a processing as distinct from a part-production nature.

In the first category is the production of "precision forgings," a technique developed for the manufacture of alloy steel turbine parts during the war. Forgings can now be produced without subsequent coining to tolerances closer than $\pm$ 0.005 in., as compared with a conventional range of 0.010 to 0.030 in. The improvement in the accuracy with which intricate castings can now be produced is well represented by the common use of the term "precision castings" for one type (lost-wax); the term could with equal appropriateness be applied to die castings, permanent mold castings and plaster mold castings, for any of which $\pm$ 0.001 in. is readily available for a wide range of smaller sizes. Plastics molding, powder metallurgy, impact extrusions, wire-forming and, most recently, electroforming are other modern manufacturing methods that broaden the parts-engineer's choice when precision production down to a few thousandths must be economically obtained.

In the second category and perhaps even more significant because less widely applied as yet are improvements in heat treating, welding, brazing and finishing that match the precision of machining and the other forming operations. Precision quenching, induction heating and selective flame hardening permit the heat treatment of parts without the need for subsequent grinding to correct distortion. Again, electric furnace brazing makes possible the construction of one small automobile engine to very close overall tolerances. And chromium plating applied to piston rings puts a hard finish and the last closely held tenth of a thousandth on these precision parts.

Engineers and production men accustomed to extracting the utmost in accuracy from the more standardized production operations should not overlook the possibilities for precision production available in some of the newer methods. We should be especially alert to maintain a matching level of precision during the preliminary or processing steps. It's a lot more efficient and economical to have precision everywhere than to have it just at one or two stages of product manufacture.

FRED P. PETERS.

Editorial Comment

Wage Incentives for Engineers

Wage incentives, in some form, have been adopted by most of our modern industries. They have been successfully applied to several types of operating employees. Even management personnel have been included, in a sense, by the adoption of bonus plans of one sort or another. Perhaps the only significant exception, where pay incentives have not as yet been attempted, has been at the engineering level.

The technical man is no different from other human beings. He shares, we ruefully concede, the same occasional tendency to lie down on the job; and he also has the same profit motive as other people, which can be exploited to get more and better work out of him. But, just as in highly scientific activities, attempts to standardize or more efficiently organize working methods have always been frowned upon in the engineering profession.

Many phases of engineering, including research, development work, designing, and laboratory work, are amenable to work measurement programs and therefore, suitable for the application of pay incentive plans. During the war a number of the varied engineering development projects of the government were closely controlled and measured with a reasonable degree of success. Recently in *Mill & Factory* (February 1946), W. M. Mirisch reported on the engineering wage incentive plan which is actually in operation at the Lockheed Aircraft Corp. From the description given there, it appears that the plan is functioning quite satisfactorily and is resulting in greater efficiency and reduction of unit operation costs in the engineering department.

Without going into the details of the Lockheed plan, suffice it to say that it does not attempt to rate individual performance, but rather measures and pays on group performance. It considers the part all the various engineering groups have in the final production drawings; it pays off on increased output from cooperative efforts of technical men.

It is obvious that wage incentives cannot be applied to all technical endeavors, and it would be a mistake to consider it a universal plan. Careful study of the engineering functions in each particular case is necessary to determine whether or not there is a sound basis on which to rate the quality and quantity of work performed. But where engineering wage incentives do appear feasible they should be adopted, for the engineer will benefit by increasing his earnings; the company will benefit by lowered unit costs; and, finally, more and better engineered products will result. —H. R. C.

The "Conditioning" of Steel

Tempering is an important operation in the process of hardening steel. It has a threefold purpose: first, to relieve stresses caused by the hardening operation; second, to induce the transformation of any austenite remaining in the steel after quenching; and, third, to reduce (or control) the hardness and increase the toughness of the hardened material.

For certain types of steel (*viz.* the high alloy tool steels such as high-speed steel) it has been found beneficial to cool the hardened work-pieces to subzero temperatures as a part of the tempering operation. While the mechanics of low temperature steel transformations (or low temperature induced transformations) are not wholly understood, it has been definitely demonstrated that the dimensional stability of gages, and the hardness and certain other physical properties of selected types of hardened tool steels are enhanced by this treatment.

In other words, some of the desirable properties in hardened tools that are supposed to be produced or improved by tempering treatments are further enhanced by subzero cooling. From this standpoint, the subzero cooling of hardened steels may be considered as a supplement to tempering. Also, the results of subzero cooling of martensitic alloy steels are complementary to tempering. Certain qualities of hardness combined with toughness result from cooling tools far below room temperature.

Since tempering conditions hardened steel for use (by relieving stresses, promoting the transformation of residual austenite, and controlling the hardness) and subzero cooling is both supplementary and complementary to tempering in its effects, it is suggested that the entire process of readying hardened steel work-pieces for their individual uses be termed "conditioning." Thus, conditioning would include those two phases of post-hardening treatments called tempering and low-temperature treatment, and we would have one simple and meaningful term for this important part of the hardening operation. —R. S. B. Jr.

The Face Toward the Past

One handicap the engineer and designer frequently encounter is the conservatism of the buyer of his products. As one of the speakers at a summer meeting of the S.A.E. put it: "Human psychology still is primitive, and even modern man demands a link with the past." Then he went on to explain that no matter how great an improvement is involved, motor vehicles or aircraft without a hood in front of the operator are not acceptable, even to the experienced, because people have become conditioned to the negligible protection and false security of the hood. (The force with which one flies through the windshield is identical with or without the hood!) This is in line with the familiar tale that the first automobiles, modeled after a buggy, had a whip socket on the dash board.

Most of this consumer prejudice, of course, involves consumer goods. Yet there are certain false and traditional conceptions among industrial products and components. In this magazine a few months back, we presented excerpts from a talk by "Boss" Kettering before a group of Detroit engineers. It seems that a certain forward-looking automotive engineer wanted to design a radically different Diesel engine piston. The smart boys laughed, as certain ones laughed at Columbus. But the pay-off was that the new piston design promoted piston life many fold.

This is one of the most appropriate periods of all in which to be liberal with new engineering ideas. Theoretically, it is the beginning of a new era—the perhaps over-publicized "postwar world." In our own field of engineering materials and methods for processing them we do have some new materials, much new information about old though less familiar materials, and many new and improved methods and processes. For the good of their proper users as well as industry in general, they should be applied wherever possible.

Consumers, be they the technically-ignorant public or the trained technician, should think twice before turning thumbs down on an idea just because it smacks of the fantastic. There are real possibilities in those auto engines made of copper-brazed steel stampings or of aluminum die castings—or in hundreds of other new mechanical and metallurgical thing-a-ma-jigs. —H. A. K.

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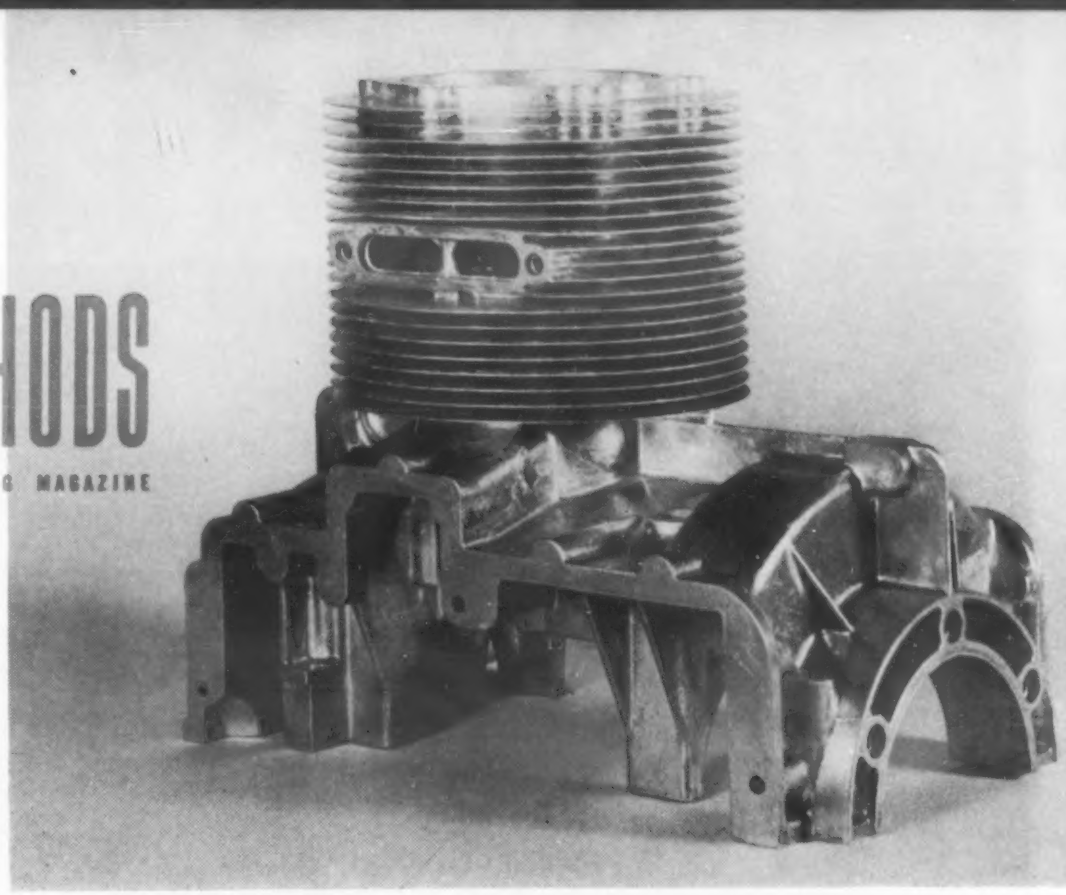


All block and cylinder head die castings of the lightweight engines will be prototy
this one for a 2-cylinder engine. Opposing castings are identical.

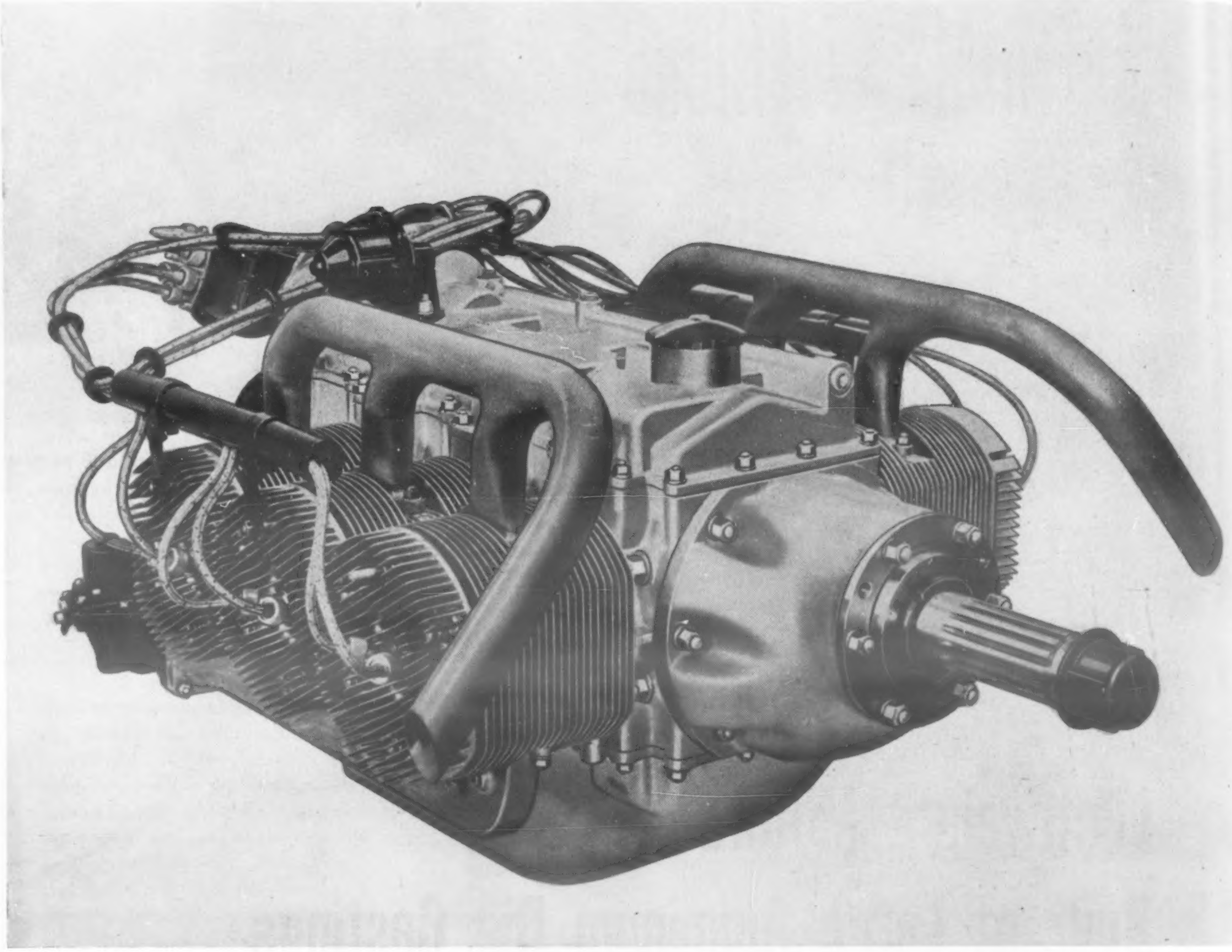
Lightweight Motors Built of Large Aluminum Die Castings

by KENNETH ROSE, *Engineering Editor*, MATERIALS & METHODS

PART OF THE RECONVERSION PROGRAM of Jack and Heintz Precision Industries, Inc., Cleveland, from their wartime manufacture of aircraft accessories provided for the production of a series of lightweight, aircraft-type internal combustion engines. The series was planned to consist of a 2-, a 4-, and a 6-cylinder motor. The 2-cylinder model was to be rated at 20 hp., the 4-cylinder at 50, and the 6-cylinder at 75 hp. They were to be offered to industry wherever the high horsepower-weight ratio of this type of engine would be of advantage.

While production of all three models was begun with aluminum sand castings, it was decided to go to die casting, if possible, to obtain high production with good quality and low cost. Die cast aluminum parts for the motor would include the motor block, cylinder head, oil pan, covers, and many smaller parts. The motor was planned essentially as an assembly of die castings.

Die castings replace aluminum sand castings for many of the large parts of 2-, 4-, and 6-cylinder aircraft-type internal combustion engines.

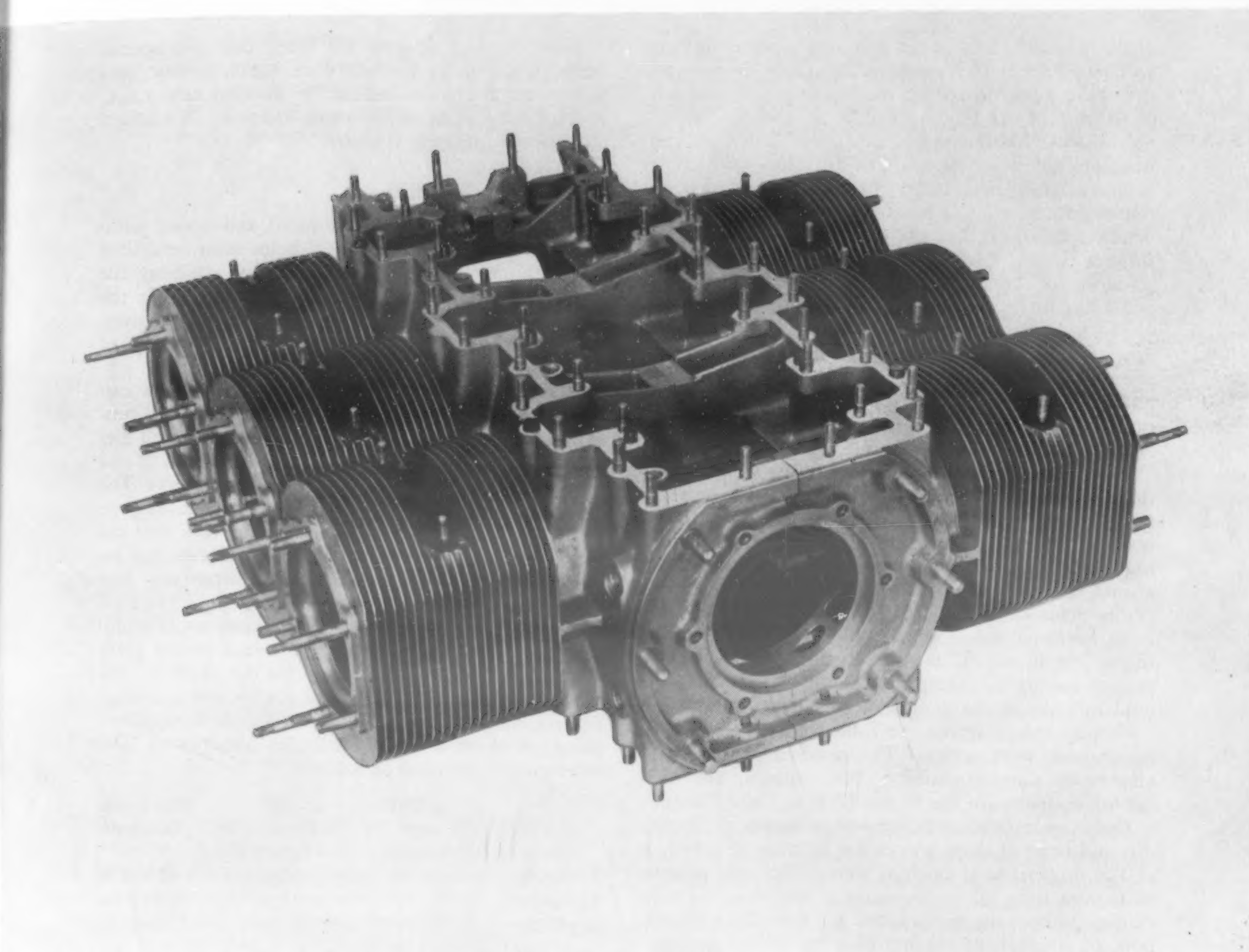


Next to be produced of die castings is the 6-cylinder engine shown here. Special die casting machines were built to produce the large castings which will weigh close to 45-lb. each, as cast.

The block for each motor was designed for construction in two halves, the halves to be bolted end-to-end, with the cylinder bores horizontal. A single motor block casting for the 2-cylinder engine would contain one cylinder, that for the 4-cylinder motor two cylinders, and so on. The halves for any motor were identical, so that no right- and left-hand castings were needed. In addition, cylinder heads, pistons, connecting rods, and all valve motions were standardized for the entire series, thus greatly reducing the number of different parts required. Since only the main castings, such as the block, crank cases, covers, etc., would be different in each type, die costs were held to a minimum also. About six to eight parts only would be different in going from one type to another.

Production of the main castings required development of dies of a size and intricacy not heretofore attempted. The motor block for the 2-cylinder engine, the first to be made, was the largest aluminum die casting of comparable intricacy yet produced. Its weight is about 15 lb. as cast, and about 13 lb. when finished. Yet the next in line of production was to be the block for the 6-cylinder engine, three times as large. Production of most of the die castings was undertaken by Westfield Manufacturing Corp., River Rouge, and by Standard Die Cast Co., Detroit.

It was found early in the consideration of the work that no available die casting machine could produce parts of the size, intricacy, accuracy, and density desired. The first step, then, became the design and building of a die casting machine, the largest in the world with the possible exception of "the" one in Germany. The machine weighs 75 tons. For production of some of the smaller die castings a second type



This entire assembly will be produced as two die castings, each identical in design. The die for this casting will weigh about 16 tons. Both casting and finishing costs will be lowered.

of machine, weighing about 20 tons, was built.

The larger machine was designed and built by Westfield Manufacturing Corp., while the smaller one was produced by Standard Die Cast Co. Both are made for use with aluminum, using the cold shot chamber, and are convertible to gooseneck casting with zinc-base alloys. The conversion would require about two day's time. Both machines are hydraulically operated, using oil for the liquid and nitrogen gas in the pressure tanks. Both can operate at pressures to 2500 lb. at the pump.

In addition to the hydraulic locking, both machines have mechanical locking by means of a toggle. Factors of safety have been kept high. The large machines are installed in separate bays, with fireproof walls, as an additional safety feature.

Electric controls are provided for the hydraulic system, permitting an automatic cycle of casting. The hydraulic system affords a wide range of speeds for the machine movements. Pyrometer controls make possible the regulation of metal temperatures to close limits.

14-Ton Motor Block Die

The die for the motor block, made by Standard Die Cast Co., is a 14-ton item embodying many new features in die casting dies that the makers are not yet ready to reveal. Production of the die required a year of development, and the work of about 50 die makers. Weighing 28,100 lb., and containing about 300 parts, not including studs and bolts, the die was developed for the production of one-half of the 2-cylinder motor block, with the still larger die for the 6-cylinder motor

block in mind. The larger die, now in construction, will weigh about 16 tons, and will include the features that have been proved in the development and use of the die for the 2-cylinder motor.

The shoe for the die is made of Meehanite cast iron, and the die cavity is of Nu-Die Steel. The cavity is not electroplated, but is highly polished, with a tremendous amount of hand work going into the finishing operations. The die cavity materials are carefully hardened, this procedure being of especial importance for the motor block dies, which must withstand very high pressures during the casting operation.

The die is so positioned that the axis of the cylinder is in the horizontal plane. Four retractible sections provide for the cooling fins, cast integrally with the block. It is gated at the flywheel and timing gear cavities, and cores are provided for all bolt holes. About 75 inserts are used in the die.

Production of the die castings was less troublesome than might have been expected. "Drags," or castings sticking in the die cavity, were rather fewer than normal. While considerable difficulty with "soldering" of the castings to the die cavity was experienced at first, development of a die spraying compound, together with careful hand polishing of the die surfaces, overcame this trouble. An extensive water cooling system in the die is also of value in maintaining proper casting conditions. The high pressures used tend to increase the danger of soldering.

Casting temperatures, carefully chosen and closely maintained, were normal. The material used is A13 aluminum alloy, containing 12% silicon, and the casting temperature was in the 1200 to 1300 F range.

Only five minor corrections were necessary in the die, and none of these was in the location of cores.

The original sand castings were sufficiently porous to require tung oil impregnation. Sectioning of test castings of both the motor block and the cylinder head, both of which have cooling fins, has shown no porosity in the die cast parts, even the fins showing dense metal.

While the cost of the die castings was lower than that of the sand cast pieces, an additional saving was realized by the lowered machining and finishing costs of the former. All oil passages, and the stud holes for fastening the cylinder heads, for fastening the two halves of the block together, for attaching the oil pan, and for fastening the top, front, and rear covers were cored in on the die caste parts, and the stud holes were held to tolerances of ± 0.003 to ± 0.005 in. These stud holes are tapped directly, without preliminary drilling. Rosan studs are used for joining the parts to be bolted.

Finishing costs were lowered by the cleaner surfaces of the die castings. This was particularly true of the cooling fins, where cleaning off adhering sand was a difficult matter.

The engine castings, delivered to the Jack and Heintz plant, are touched up with a belt sander to remove flash, and the pairing surfaces are milled off. Castings are then bolted into pairs to form the motor block, and are treated as a unit thereafter. Top and bottom surfaces are milled off, and the cored holes are tapped for the studs.

Main bearing supports are bored out with special boring equipment. Cylinders are bored, ground, and honed to a smoothness of 5 microinches, r.m.s., average roughness, on the inside diameter. A nitrided steel sleeve lines the cylinder.

Six Holes to be Drilled

While all the stud holes are cored, and tapped without other machining, six dowel holes must be drilled and reamed. These are the dowels for attaching the cover and pan. The oil pump drive is located in the pan, and the accessory drives are placed in the cover, the accurate alignment required making coring of these holes impossible.

While emphasis has been placed upon the die cast motor block, the largest and most difficult of the castings to produce, the motor is to all intents an all-die-cast engine. The cylinder head, with cooling fins and a keyed-in brass insert, is also a difficult piece. The oil pan, accessory cover, and front and rear covers; the main bearing block, with a steel insert cast into the inside diameter; the valve supports, all castings required for the engine accessories, carbureter, fuel pump, etc., are all die castings.

The series of motors was planned to make available for the automobile or other user a power plant of the same weight ratio as that for the airplane. For this reason aluminum was used for all main castings and for most of the accessories. Weight-horsepower ratios are of the order of 1.2 lb. per horsepower. The three motors are rated as follows:

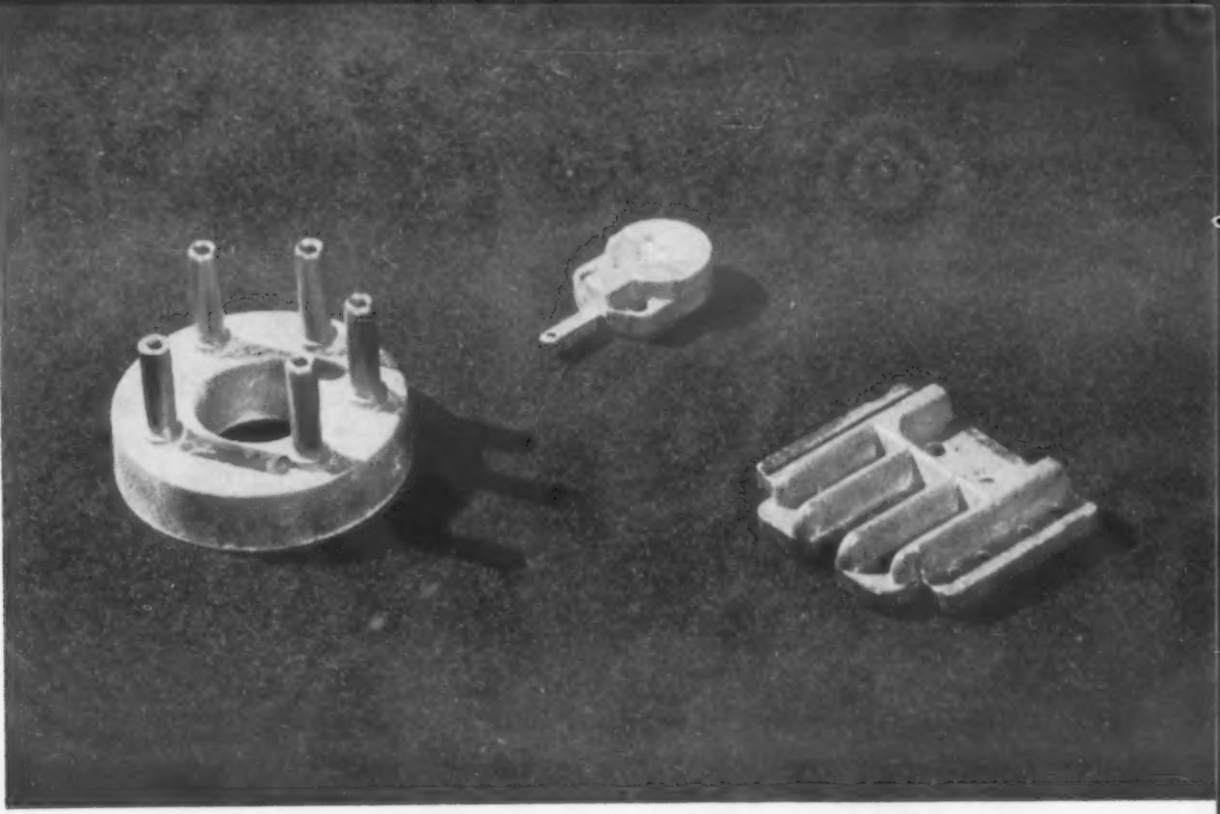
	at 4500 r.p.m. (rated)	at 6000 r.p.m. (Peak)	piston displacement
2-cylinder	20 hp.	30 hp.	42 cu. in.
4-cylinder	50 hp.	60 hp.	84 cu. in.
6-cylinder	75 hp.	95 hp.	126 cu. in.

At present, production of the die cast motors is confined to the 2-cylinder model. Work is proceeding upon the die for the motor block for the largest, the 6-cylinder engine. The 4-cylinder motor will be undertaken later.

The die casting for one-half of the 6-cylinder motor block will be the largest and most difficult part in the entire group to produce. It will weigh about 30 lb., and will include three cylinders, with the necessary cooling fins cast integrally with each cylinder. The die for this casting will follow the engineering principles used successfully for the smaller motor block. Planning of the entire project was done in advance so that the largest motor block die can be used on the die casting machine now in use for the 2-cylinder die. The die itself will be only slightly larger—16 tons as compared to 14 tons for the present motor block die.

The motors have performed satisfactorily under test when built from aluminum sand castings. Tests upon the 2-cylinder motor made from die-cast aluminum parts have shown equally satisfactory performance of the completed motor, while examination of the die cast parts has shown greater density and freedom from defects than with the sand castings. Density was reported as comparable to forgings.

The photo-flash tube base at the left is representative of parts produced from G-E mycalex. That material resists extreme heat and arcing.



Stone-Like Plastic Formed by Molding

by T. C. DU MOND, *Managing Editor*, MATERIALS & METHODS

TO THE MATERIALS which are now available for forming by compression or injection molding can be added a composition which is stone-like in feel and appearance with a grayish color. Made of mica and a special soft glass binder, the material is known as G-E mycalex and is produced by General Electric Co.

The uses of G-E mycalex up to this point have chiefly been in the field of electronics, but the material is expected to find application in rotating equipment, heating devices, motor parts, welding equipment and for many other types of products. Present uses include: vacuum tube bases, insulators of various types, coil supports, switch parts, coil forms and supports, heater terminals, brush holder studs and inserts in cutout boxes.

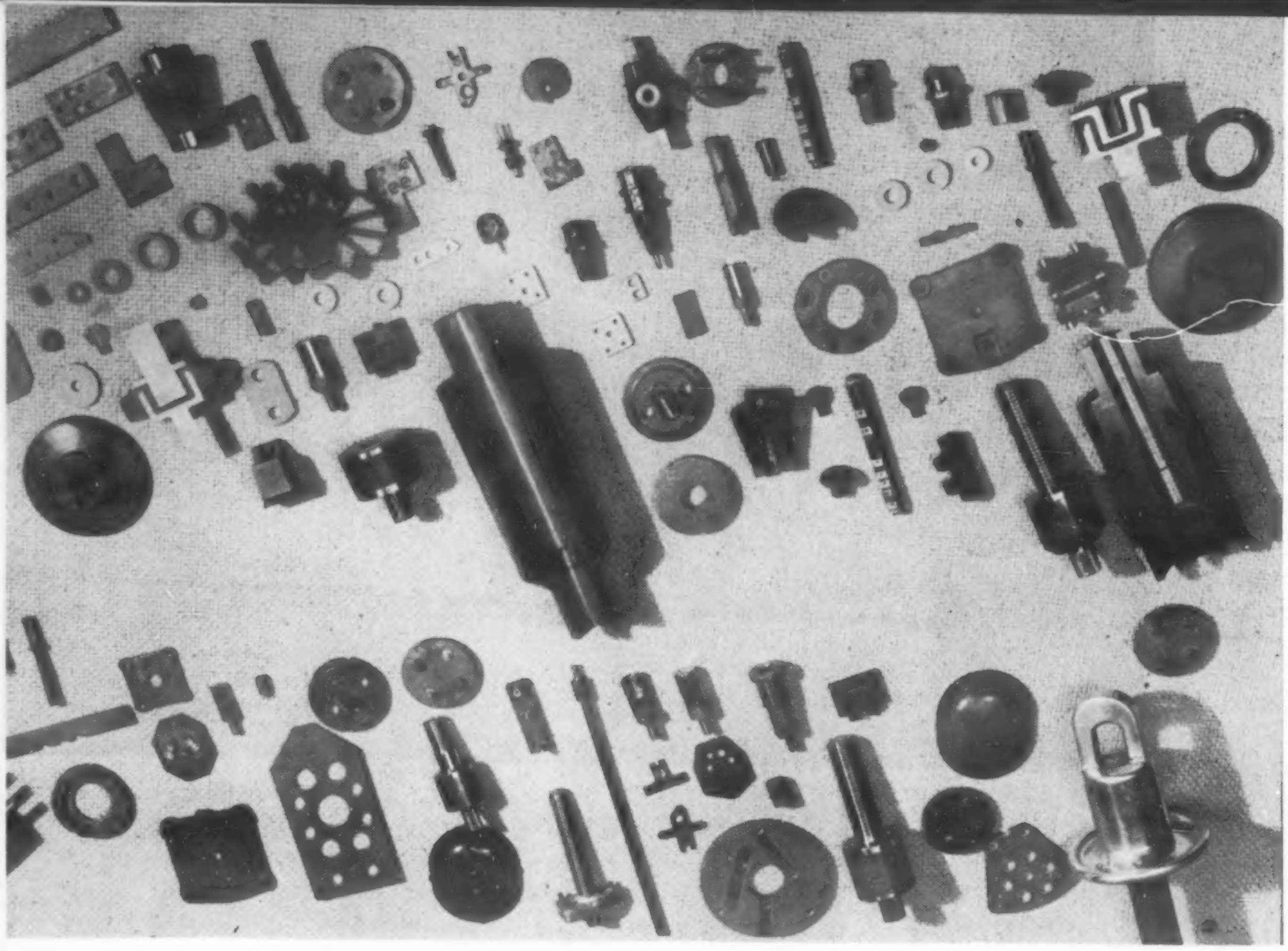
Special properties of G-E mycalex make it particularly suited to electrical applications where its stability at high operating temperatures and under changing atmospheric conditions, its high arc resistance, high electrical and mechanical strength and low dielectric power loss are important characteristics. In addition, it can be molded to close tolerances not possible with other inorganic materials.

Mica and soft glass are combined to produce a material that has many favorable characteristics especially suitable for electrical applications.

At present there are six grades of G-E mycalex available—four for compression molding applications and two for injection molding. All grades can be sawed, turned, drilled, ground and polished, despite their stoney hardness. Too, simple shapes such as washers can be punched from thin sheets of the material.

G-E mycalex is said to equal or excel in electrical and mechanical properties other types of materials used for similar electrical applications including cold-molded refractory materials, hot-molded phenolics, wet-process porcelain and steatite. In addition, metal inserts can be readily molded in place with satisfactory accuracy. Too, aluminum alloys can be cast around G-E mycalex without softening, blistering or affecting in any other ways the material's structure. By this latter method, fittings can be cast over the ends of rods to form strain insulators without machining and fastening the fixture by sealing-metal.

While one of the advantages of G-E mycalex is that metal inserts can be molded in place G-E mycalex parts in turn can be used as inserts in phenolic-molded parts, by anchoring in the same manner as metal inserts.



Shown here are a variety of parts made partially or completely of G-E mycalex.

Physical properties of G-E mycalex remain unchanged at temperatures up to 662 F unless it is subjected to high mechanical stresses. At temperatures higher than 572 F it may deflect or deform when subjected to mechanical stress, the effect depending upon temperature, magnitude and nature of mechanical stress, design of part and duration of the adverse condition.

Design Considerations

As with parts produced of other molding materials, parts designed for G-E mycalex and produced by injection molding should provide good plastic flow, have generous contours, round corners and be free of abrupt changes in cross-section. Size of available injection molding equipment limits G-E mycalex parts to those having approximately 12 sq. in. area. Larger parts often are produced by compression molding.

Recommended minimum thickness of G-E mycalex parts is about 1/16 in. although vertical walls as thin as 1/32 in. have been molded. Undercuts are generally avoided because of the difficulty in extracting parts from the mold. When undercuts and right angle holes are necessary generous tapers and contours are required.

The need for ample tapers is due to the fact that G-E mycalex conforms exactly to mold cavity contours without shrinkage. It has been found from experience that for the average part a taper of 2-deg. per side, or 0.032 in. per in. is necessary for proper ejection.

Generally, holes ¼-in. dia. and less and slots up to ¼-in. wide should not be more than 1½ times their diameter or width in depth. Holes larger than ¼-in. should not be longer than twice their diameter. Longer holes can be drilled or molded by special methods when essential. Distances between holes should be at least ⅛ in. and holes should be over 1/16 in. from the parts edge.

There are certain design limitations which must be considered in selecting G-E mycalex, many of which have little or no effect on function of the final part. For instance, Army electronics standards for parts machined from standard plates and rods suggests that rectangular parts with right angle corners are simpler and cheaper to make. Where sharp corners must be eliminated a chamfer is suggested. Internally, round holes are preferred over square, rectangular, or elongated holes, or holes with keyways. Too, although holes can be tapped, such holes should be avoided if possible. This list of "don'ts" is set up to avoid excessive costs, not because such shapes and forms are impossible to obtain.

Metal inserts are readily molded in G-E mycalex if anchored by knurling, grooving or threading. Knurling is preferred as the bond between the part and insert is purely mechanical. Metal used for inserts must withstand heat up to 1400 F and approximately 40,000 psi. molding pressure.

Machining

G-E mycalex should be cut by means of abrasive wheels operating at about 2500 r.p.m. although material under ¼ in. thick can be cut by means of a low-speed bandsaw. Milling, drilling, and turning are best done with carbide tipped tools. Grinding of surfaces, contours and undercuts is satisfactorily done by means of a medium-grained silicon carbide wheel with water used as a coolant and to prevent wheel loading.

Since many parts can be cut or machined from standard sheet and rod, G-E mycalex is stocked in plates 14 x 18 in. in thickness from ⅛ to 1 in.; strips 1 to 2½ in. wide; 24½ in. long, and from ¼ to 1¼ in. thick; octagonal rods 12 in. long by ⅛ and 1⅜ in. across flats, and round rods from 14 to 18 in. long and with diameters from ¼ to 1 in.

Washers with thicknesses of up to ⅜ in. can be

punched by heating the sheet material in an oven to between 925 and 1000 F and then transferred to the die and punched while hot. It is also possible similarly to shape simple pieces of other forms.

Properties

Electrical and mechanical properties vary among the various grades of G-E mycalex, so a general range of properties may serve to show suitability of the materials for various applications. Some mechanical property ranges are (all at 25 C) flexural strength, 9,000 to 26,000 psi.; modulus of elasticity, 7.2×10^6 to 11.6 $\times 10^6$; tensile strength, 5,000 to 13,000 psi.; compressive strength, 22,500 to 52,000 psi.; resistance to impact, (Izod), 0.7 to 1.86 ft. lb./in. of notch; hardness, 80-105 Rockwell K to 22 Rockwell L density 0.103 to 0.115 lb. per cu. in.; specific gravity, 2.85 to 3.6.

Mechanical and Electrical Properties

Property	Test Condition	Method of Test		Compression Molded			Injection Molded	
			No. 2821	No. 1360	No. 1363	No. 1364	No. 2802	No. 2803
Flexural Strength (Lb./sq. in.)	At 77 F	ASTM D650-42T	18,000 to 26,000	15,000 to 20,000	9,000 to 12,000	14,000 to 19,000	11,000 to 14,000	11,000 to 14,000
Modulus of Elasticity in Flexure (Lb./sq. in.)	At 77 F						7.0 to 7.5	8.0×10^6
Tensile Strength (Lb./sq. in.)	At 77 F	ASTM D651-41T		5,000 to 7,000			5,000 to 7,000	5,000 to 7,000
Compressive Strength (Lb./sq. in.)	At 77 F	ASTM D649-42T	39,000 to 52,000	22,000 to 30,000		30,000 minimum	22,500 to 27,500	27,500 to 30,000
Resistance to Impact (Ft-lb./in. of notch)	Izod test at 77 F	ASTM D256-43T					4.37	3.90
Hardness	At 77 F	Rockwell	22-L	22-L		22-L	80-105K	80-105K
Water Absorption (% in 24 hr.)	At 77 F	ASTM D570-40T	Nil to 0.002	0.03	0.8 to 2.5	0.003	Nil	Nil
Heat Distortion		ASTM D648-41T	300+	300+	300+	300+	300+	300+
Coef. of Linear Expansion (In./C)	Temp. range 68 F to 662 F		10×10^{-6}	8×10^{-6}			10.9×10^{-6}	11.7×10^{-6}
Thermal Conductivity (Cal./sec./sq. cm./C /cm. X 10^{-3})				1.36		1.49	1.3	0.95
Specific Heat (Cal./C/cm.)							0.08	0.05
Density (Lb. per cu. in.)			0.115	0.124	0.103	0.106	0.130	0.095
Specific Gravity			3.2	3.44	2.85	2.95	3.6	2.64
Color			Gray	Gray	Gray	Gray	Gray	Gray
Surface			Very Smooth	Slightly Rough	Rough	Smooth	Very Smooth	Very Smooth
Power Factor (PF)	60 cycles at 77 F (dry) 1 megacycle at 77 F (dry) 1 megacycle after 2 days in H_2O 1 megacycle after 3 days in H_2O 1 megacycle after 60 days in H_2O 12 megacycles at 77 F (dry) 30 megacycles at 77 F (dry)	ASTM D150-42T	0.007 0.0011 0.0018 0.0018 0.0011			0.0022 0.003 0.0035	0.007 0.0014 0.0018 0.0013	0.0025 0.0040
Dielectric Constant (K)	60 cycles at 77 F (dry) 1 megacycle at 77 F (dry) 1 megacycle after 2 days in H_2O 1 megacycle after 3 days in H_2O 1 megacycle after 60 days in H_2O 12 megacycles at 77 F (dry) 30 megacycles at 77 F (dry)	ASTM D150-42T	7.6 7.85 7.85 7.85 7.85			7.5	9.25 9.18 9.20 9.12	7.1 7.1
Loss Factor (PF X K)	60 cycles at 77 F (dry) 1 megacycle at 77 F (dry) 1 megacycle after 2 days in H_2O 1 megacycle after 3 days in H_2O 1 megacycle after 60 days in H_2O 12 megacycles at 77 F (dry) 30 megacycles at 77 F (dry)	ASTM D150-42T	0.053 0.0086 0.014 0.014 0.0086			0.017 0.023 0.026	0.065 0.013 0.017 0.012	0.018
Dielectric Strength Volts/Mil (Thickness—0.2 in.)	60 cycles 77 F short time 60 cycles 77 F step by step 60 cycles 212 F short time 60 cycles 212 F step by step	ASTM D116-42	475	340 340	250	360	320 320 375 375	400 400 425 425
Volume Resistivity (Ohms-Cm.)	At 77 F	ASTM D257-38	4.8×10^{13}				2.0×10^{13}	12.4×10^{13}
Surface Resistivity (Ohms/sq. in.)	At 50% relative humidity, 77 F after 72 hr. at 90% relative humidity	ASTM D257-38	3.0×10^{12} 1.7×10^{8}					
Arc Resistance—Sec.	At 77 F	ASTM D495-42	267	325	330	260	250	244

Heat resistance, heat reflectivity and corrosion resistance are high in this material which found application in aircraft fire-walls and flexible pipes.

Aluminum Dipcoated Steel

A New Material Preview

IN THE LAST YEAR OF CIVILIAN production before the entry of the United States into the war, a new metallic coated material was offered to American industry. Sheet steel was successfully dipcoated with aluminum to produce a coated material that could take its place with tin plate, terne plate, and galvanized sheet in the array of corrosion resistant sheet steels available to the materials engineer and the product designer. Before its advantages could be studied and utilized, the channeling of metals into war production had begun, and aluminum coated steel went to war. Now, with its honorable discharge, it is again being offered for the consideration of the metal fabricating industry.

Aluminum coated steel has as its special advantages good corrosion resistance, heat resistance, and heat reflectivity. One of the few prewar applications in which it had been tried was in the construction of automobile mufflers. Its resistance to deterioration at elevated temperatures was sufficiently marked to warrant its preference over both plain steel and terne plate. Its wartime use for such parts as the flexible tail pipe for some models of "jeeps" and for fire-walls in military planes followed. It is now being used for fire-walls in commercial aircraft, for oven liners in domestic ranges, for heat exchanger tubes, and for many similar purposes.

The sheet is continuously coated by a hot dipping process patented by The American Rolling Mill Co., and is offered by that company under the trade name Armco Aluminized Steel. The weight of aluminum applied is the same for all gages. Approximately 0.50 oz. of the coating metal is retained on a square foot of the coated sheet, this being the total aluminum on both sides. The actual thickness of the aluminum film is about 0.001 in. on each side, however—much thicker than terne plate or tin plate coatings of the same weight, due to the lower specific weight of the aluminum. It is about as thick as the standard galvanized coating, but more than two and one-half times as much zinc, by weight, is applied to obtain this thickness. A terne coating of the same thickness would require almost four times as much adhering metal, and a tin plate would need to contain more than two and one-half times the coating weight to offer the same coating thickness. Such tin and terne coatings are not produced commercially.

Corrosion resistance, as determined by salt spray tests, is excellent. Laboratory tests in 20% salt spray at 95 F have shown a coating life of 1000 to 2000 hr., while a standard 1 oz. galvanized coating endured for only 100 to 130 hr. under the same conditions before rusting of the base metal.

Samples are now undergoing test at Kure Beach, North Carolina. Preliminary observations are very favorable. In these tests in a marine atmosphere the loss of weight of aluminum coated steel average about one-fifth that of galvanized sheets. In mild industrial atmospheres the performance of the aluminum coated samples was even better, averaging only about one-tenth the loss of weight of zinc coated sheet.

No Discoloration at 900 F

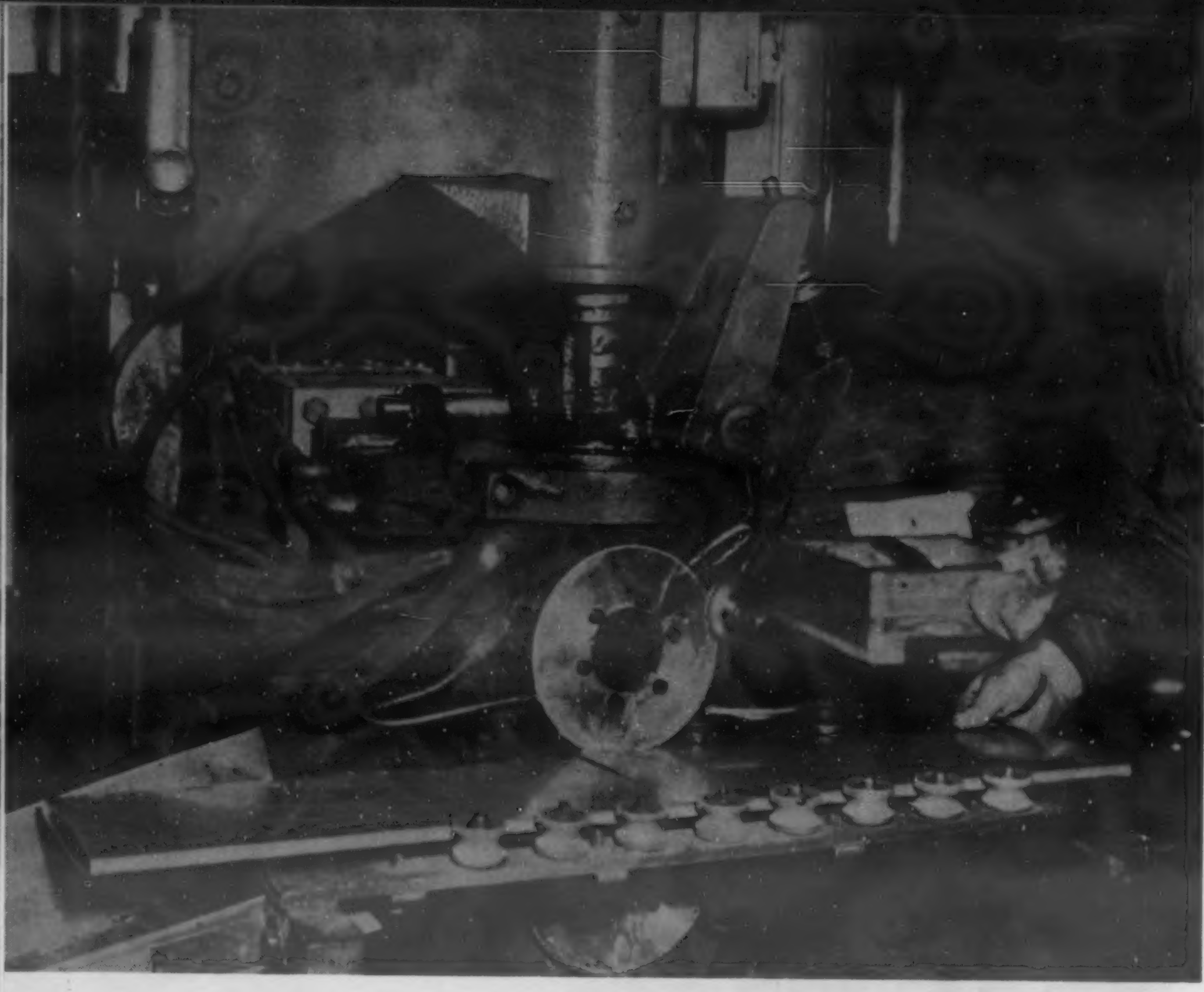
Closely connected to the corrosion resistance of the new coated steel is its resistance to oxidation at

Here a long, wide strip of cold rolled steel is coated with aluminum by a continuous process.

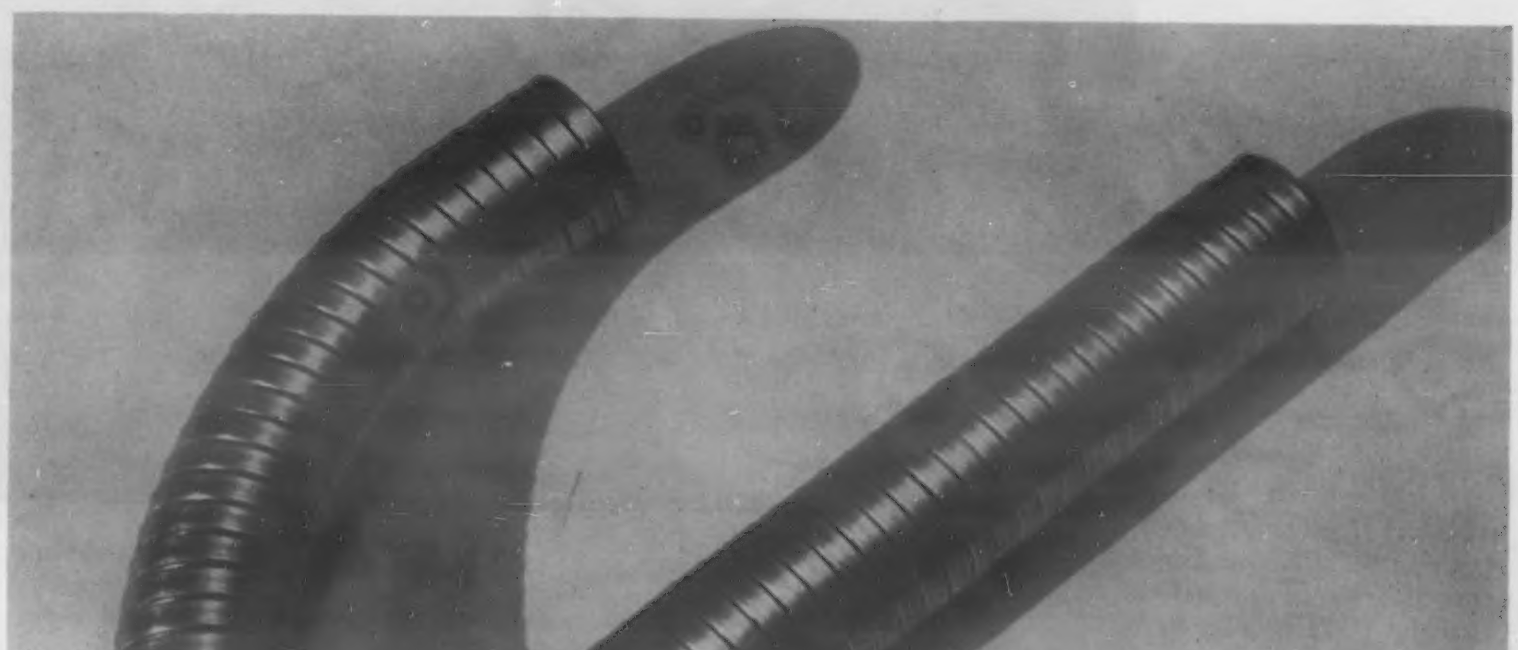
elevated temperatures. Exposure to heat up to about 900 F does not produce discoloration, thus keeping reflectance of heat and light at a high value. At temperatures above 900 F the aluminum coating begins to alloy with the iron in the base metal. Formation of the alloy proceeds rapidly above about 1200 F, as the aluminum reaches its melting point. The alloy resists destructive scaling to about 1600 F. At temperatures of about 2000 F the alloy disintegrates into a whitish, oxidized scale.

The formation of the iron-aluminum alloy after exposure to temperatures above 1200 F means that after such exposure the material has changed its essential composition, and has ceased to be an aluminum coated steel. This effect is of course not reversible. The alloy coating possesses good refractory properties, but is less corrosion resistant than the original aluminum surface. Its corrosion resistance is superior to that of mild steel, however. In a series of cyclic tests performed by The American Rolling Mill Co., specimens were alternately heated to a designated temperature, held at temperature for 30 min., permitted to cool for 10 min., then reheated, the cycle being repeated 20 times. Temperatures of 1200, 1400, 1600, 1800, and 2000 F were used. The 1600 F specimens showed little deterioration and those subjected to lower temperatures showed no effects of destructive oxidation.

This material has shown superior performance when used for mufflers, combustion chambers of gas-



Seam welding of 0.040-in. aluminized steel for heat exchanger tubes.



Favorable forming characteristics and resistance to high temperatures and corrosion led to the use of this material for the flexible tail pipes on some models of jeeps.

fired warm air heating furnaces, heat exchanger tubes, etc. In this type of application the coated steel must resist not only destructive scaling at elevated temperatures, but the corrosive effects of the products of combustion and their condensates.

The combination of heat resistance and good heat and light reflectivity are of importance in such applications as heat deflectors for electric ranges, oven liners for kitchen ranges, oven linings and main bodies of coal- or wood-fired ranges. Heat reflectance increases thermal efficiency, while reflection of light increases visibility in the oven interior. The resistance to heat discoloration helps to maintain these advantages, and to keep an attractive appearance.

As ordinarily produced, the coated sheet has a satiny appearance similar to that of a sheet of aluminum. This is the standard "dull" finish, used for most purposes. If greater reflectivity is required a brighter surface can be obtained with the "extra smooth" grade. Buffed finishes can be prepared if desired.

A comparison of heat reflectivity of the aluminum coated steel with stainless steel and with several porcelain enamel finishes, made by estimating infra-red reflectance from a heated coil at 700 F, placed the materials in the following order:

1—Stainless steel, #7 finish
2—Aluminized steel, buffed finish
3—Stainless steel, #4 finish
4—Aluminized steel, extra smooth finish
5—Aluminized steel, dull finish
6—Stainless steel, #2 finish
7—Porcelain enamel, white coat
8—Porcelain enamel, blue ground coat
9—Black iron

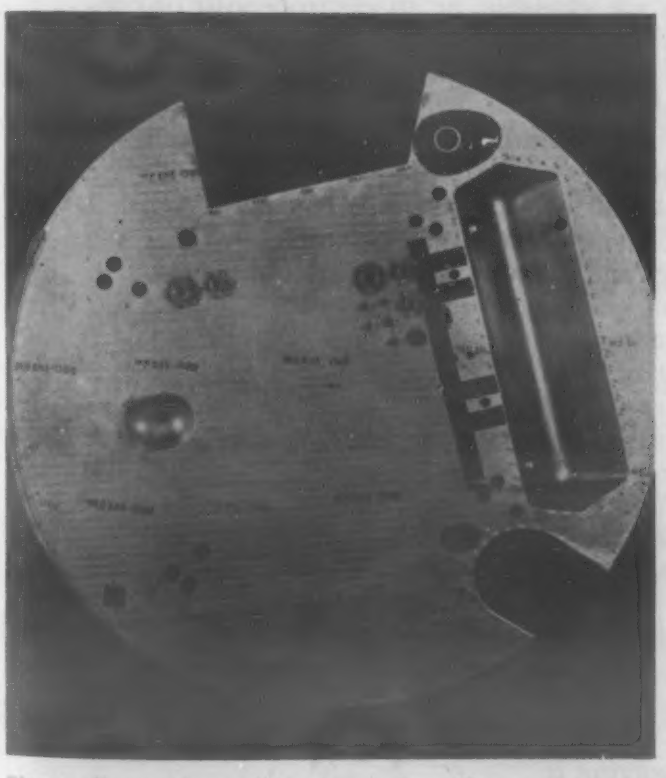
The comparison was made in the laboratories of The American Rolling Mill Co.

Several Steel Bases

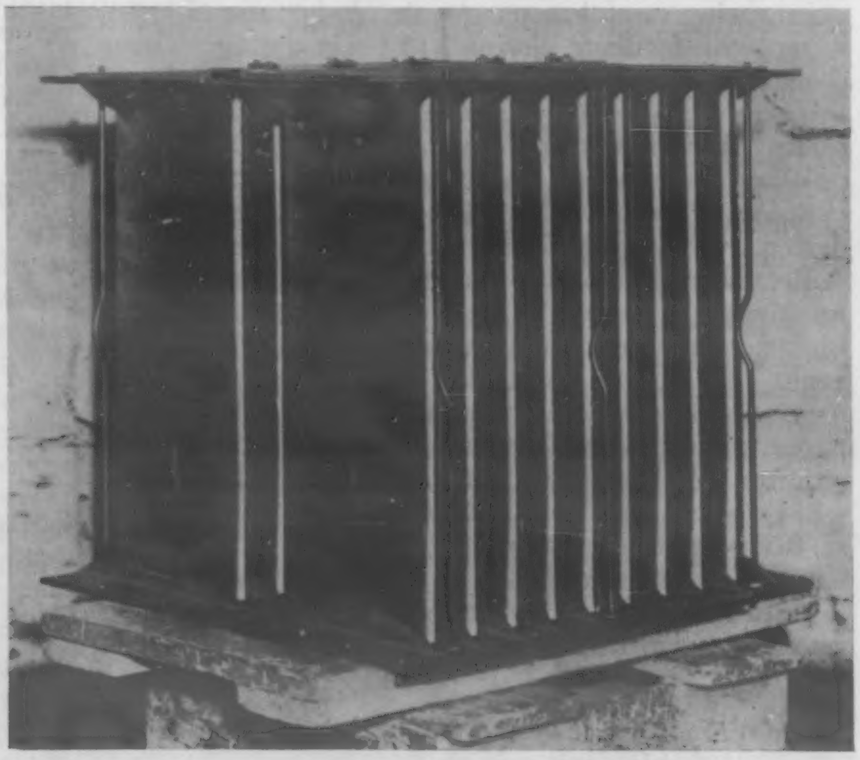
While the aluminum coated sheet is ordinarily supplied with a low-carbon steel base, it can be obtained in a copper-bearing grade, or with a high strength base. For applications requiring higher strength properties than are available with the mild steel, a low-alloy high strength steel, either 50Y or 55Y, can be coated. Physical properties are largely determined by the base metal used, since the aluminum coating is the same for all types. The following values are suitable for design purposes:

	Yield Strength	Tensile Strength	Elongation in 2 in.	Rockwell Hardness
Low-carbon base or copper-bearing base	30,000 psi. min.	45,000 psi. min.	15-25%	B-70 max.
Low-alloy high strength base (50Y or 55Y)	50,000-60,000 psi.	65,000-80,000 psi.	12-20%	B-70 to B-85

Aluminum coated steel is suitable for fabrication by most of the standard procedures. It can be formed and drawn in moderately severe operations without peeling or flaking of the aluminum. The sheet can be bent over a diameter twice its thickness without damage. While the material can be given a moderate draw without danger of flaking of the coating, the aluminum surface is soft, and may be damaged by the scraping action of the dies unless adequate clearance and lubrication are provided.



Fire walls, such as this, for both military and commercial aircraft are being made of aluminized steel.



Increased tube life in heat exchangers is said to result from the use of dipcoated steel rather than plain sheet steel.

Can Be Welded

Oxyacetylene welding can be accomplished successfully if a few simple precautions are observed. First, the work should be so fitted that a continuous steel-to-steel contact and fusion can be obtained. Second, a suitable flux must be used to remove the aluminum oxide film as slag during the fusion of the metals. If the oxide is permitted to mix with the molten steel a porous weld will result. Solar Welding Flux No. 16 GH has been found satisfactory for removal of the oxide in the film always present over the aluminum surface, and the additional oxide formed during welding. For use, it is made into a paste with technical grade methanol having less than 2% water content, and applied directly to the seam. Both top and bottom of the seam should be fluxed before welding. If a filler rod is used, it too should be fluxed with the same paste. Oxweld No. 1 HT Steel Rod has been used for filler metal.

The flux should be completely removed after welding, as the chemicals it contains will attack the metal in the presence of moisture.

Arc welding is not difficult if the electrode selected has a coating capable of dissolving the aluminum oxide. Stainless steel rod, in either the 18-8 or the 25-12 analysis, give good results. A less expensive electrode is the Raco Fer-Al, made by Reid Avery Co., Baltimore.

Resistance welding techniques resemble those for joining aluminum more than those for steel. Aluminized sheets can be satisfactorily welded exactly as they come from the mill but cleaning is advisable when the surface is soiled by handling in fabrication or by application of drawing compounds. A procedure used successfully by several fabricators consists of: (1) cleaning with a degreaser, or with hot soap solution; (2) rinsing in hot water; (3) pickling in cold 3% hydrofluoric acid; (4) rinsing in running water, being careful to remove the sludge; use of hot water will facilitate drying; (5) air drying. The sheets should be protected from contamination after this cleaning procedure, and handled with the same care as is needed with aluminum sheet.

When the nature of the work is such that chemical cleaning is not suitable, a light pass with a power-driven wire brush will clean the surfaces acceptably.

Because the aluminum coating lowers the electrical resistivity of the work, this coated steel requires a higher energy input than uncoated steel of similar gage. The increase required is higher for the lighter gages, in which the aluminum coating constitutes a larger percentage of the total thickness. Amperage requirements for coated sheets 0.018 in. and lighter will be up to 70% greater than for plain steel, while at 0.080 in. thickness only about 30% increase in amperage is required.

Adjustments for spot welding that have given good results in aircraft plants during the war are:

(1) Current duration should be 2 cycles. Longer application of current increases the tendency toward flashing and spitting.

(2) Electrode force should be about 625 to 700 lb. when welding the coated sheet to similar material, or to uncoated mild steel. When welding to stainless steel these values should be increased to 950 to 1000 lb.

(3) Squeeze time and hold time do not seem to affect the welds, and should be adjusted to whatever quantities will permit the desired rate of welding.

(4) Set the transformer tap and the heat control dial to low current values, and make a series of welds in scrap material, increasing the current until flashing and spitting occur. The heat dial is then turned back until spitting stops. This current setting will be higher than that for mild steel. If test welds are satisfactory the work may be started at these settings.

These settings have given good results with 100 kva. machines and with 0.020 to 0.040 in. material. If the work is to be done on a lighter welder, with lower amperage, current duration must be increased to obtain equivalent energy input. Smaller radius tips can be used to increase the current density, provided tests have shown adequate strength in the resulting welds.

Seam welding offers no difficulties. To reduce pick-up of the aluminum coating, streams of water should be played on both upper and lower wheels, and some provision should be made for continuous cleaning of the wheels. Knurled driving pinions help to keep the wheels free of adhering aluminum.

With lighter gages of the aluminum coated steel atomic hydrogen welding gives good results. The same welding flux is used as for oxyacetylene welding. Brazing can be accomplished with a high-strength aluminum alloy brazing rod and a flux such as Brazing Flux No. 33 of Aluminum Co. of America. Eutectic Rod No. 190 and Eutectic Flux No. 190 also give satisfactory results. Soldering presents the same difficulties as with aluminum itself. Special fluxes and procedures are available, or an electrodeposit of copper or nickel may be laid down, and the soldering performed on the plated metal.

Welding methods usually cause the removal of some of the aluminum coating, and corrosion resistance is consequently reduced. The aluminum surface can be restored by spraying the welded joints. Sand blasting to remove slag and oxides must precede the metallizing, and a protective mask must be used to prevent the sand blast from damaging adjacent aluminum coating.

Painting of the aluminum surface is not required for most applications. When some special purpose makes painting desirable a bonderizing treatment is advisable to assure paint adherence.

Aluminum dipcoated sheet is available in thicknesses from 0.0889 in. to 0.0296 in., to 38½ in. widths; and in 0.0295 to 0.0179 in. and .089 in. to 0.135 in. thicknesses to 36-in. widths. If required, a lighter sheet of from 0.0178 to 0.0148 in. thickness can be had in widths to 30 in. Since the sheet is lighter than a corresponding gage of solid steel, the steel gage-weight standards cannot be used for calculations involving it.

The coated sheet costs approximately twice as much as a galvanized sheet of the same thickness.

While of great value in many applications, the vapor cleaning method and the solvents used should be chosen with full knowledge of all problems involved.

Vapor Degreasing

by GEORGE BLACK

Although the acceptance of vapor degreasing as an industrial tool in the United States is of relatively recent date, it is estimated that there are well over 30,000 operating units in use today. The tremendous emphasis on metal working during the war years is responsible for much of this increase, but, on the other hand, the inherent advantages of vapor degreasing as a safe, efficient and economical means of removing grease, oil and wax were bound to be recognized.

In the early stages of development, degreasing equipment was designed almost exclusively for trichlorethylene—a halogenated, chlorinated hydrocarbon liquid with a sweet chloroform odor. During the past few years there has been extensive successful research with perchlorethylene—a similar liquid with properties particularly useful in degreasing units. It is the purpose of this article to discuss the properties of these two solvents, as a guide to the engineer or industrialist who is interested in installing degreasing equipment, or in securing maximum benefits from equipment already installed.

Fundamentally, vapor degreasing is the process of removing surface contamination through vapor condensation. Material being cleaned is lowered into a vat or container, in which a chlorinated solvent has been vaporized, and, as the vapors condense on the relatively cold metal, the fluid condensate dissolves and removes the contamination.

Conventional degreasing units consist of an open top tank with a lower sump which houses the liquid chlorinated solvent. Provision is made for heating the solvent to the boiling point so that vapors will be generated. As these vapors rise they condense on the surface of the work being cleaned, and then drain back into the sump to be revaporized. Control mechanisms such as water jackets, water pipes or thermostatic switches can be used to control the upper limit of these vapors so that they do not escape into the surrounding air. Latest developments have shown the practicability of portable degreasers which operate from electric outlets. These portable units, using perchlorethylene as their solvent, eliminate the necessity of gas, steam or water lines, and have grown immensely popular during the past few years because they can be brought to the assembly line. If used intelligently, they can save the hundreds of hours now wasted in transportation to and from fixed installations.

Perhaps the most important question in any discussion of cleaning solvents is that which relates to the potential fire hazard. It can definitely be stated that neither trichlor nor perchlor is explosive. At ordinary temperatures both solvents are classed as non-flammable, with no listed flash or fire points. Trichlor however, is classed as moderately flammable at higher temperatures, having a fire hazard rating of 3. Perchlor is classed non-flammable at any temperature.

In the early stages of research, attempts were made to use carbon tetrachloride for vapor degreasing. Long observation and toxicological study has shown that carbon tet is highly toxic and harmful in open tank application. In addition, its low boiling point, and light, easily diffused vapors are not suitable for vapor degreasing. These reasons for rejection must be considered in our discussion of trichlor and perchlor. Let us look first at the health picture.

Health Problems

All of the chlorinated hydrocarbons have some anesthetic properties, and will cause dizziness and nausea when inhaled in heavy concentrations. Extended breathing of excessive quantities will cause a loss of consciousness. It should be obvious therefore,

that intelligent precautions in the use and handling of these solvents must be observed.

The most complete and thorough data compilation relative to the maximum allowable concentrations of industrial gases and fumes, was made by the Massachusetts Industrial Commission. The table furnished by this commission lists the following permissible concentrations:

Carbon tetrachloride . 100 parts per million in air (CCl_4)
Trichlorethylene .... 200 parts per million in air ($CHCCl:CCl_2$)
Perchlorethylene .... 200 parts per million in air ($CCl_2:CCl_2$)

In comparing the effects of the two latter solvents, Doctor Alice Hamilton, Director of the United States Department of Labor, Division of Labor Standards, stated that perchlor is the safest of all the chlorethylenes. In addition, although perchlor will affect the mucous membranes, if inhaled in sufficiently concentrated volume, it will not, as will trichlor, affect the liver and kidneys.

Health precautions make regular tests of existing concentrations a must item. Industrial divisions of most state health departments have equipment for determining exact concentrations, and will gladly make the investigations at the request of management. The use of "Halide Lamps," where methanol is ignited around a copper screen and comparisons made of the colors of the flame during combustion in an area containing chlorinated solvents is not recommended as a true guide or control. The Mine Safety Appliance Co. has developed an ultra-violet photometer which is sensitive to both trichlor and perchlor and makes possible immediate recognition of hazardous concentrations.

As stated above, weight is an important vapor characteristic. Since degreasing is performed in open top tanks, the vapor used must be substantially heavier than air or excessive escape into the surrounding atmosphere will be inevitable. Both trichlor and perchlor have exceptionally heavy vapor weight but perchlor is the heavier of the two. The relative weight of these vapors to that of air is approximately 4.3 times for trichlor and 5.7 times for perchlor. In addition, the 100% evaporation of perchlor is better than three times as slow as trichlor.

Since the basis of effective degreasing lies in the temperature differential between the material being cleaned and the vapor itself, consideration must be given to this characteristic of the solvents. The constant temperature of perchlorethylene is 249.8 F. This is 61 F higher than that of trichlor which is listed as having a vapor temperature of 188.8 F. The higher the vapor temperature, the longer the period of condensation, and consequently, the greater the cleaning efficiency. This is particularly true for the cleaning of light or thin material which heats up so rapidly that the lower boiling solvents hardly get started before condensation ceases. It should be noted, however, that the lower boiling point of trichlor permits the use of low steam pressures and simplifies removal and handling of degreased material. Trichlorethylene, as prepared for use in vapor degreasers is slightly soluble in water. In order to prevent acid attack due to hydrolysis, it is ordinarily inhibited at the source of manufacture. It is claimed that this inhibited trichlorethylene is non-corrosive to metals. However, attack can occur, especially if parts being cleaned are nested so that the condensate is pocketed. Since perchlor vaporizes at a temperature well above the boiling point of water, acid attack due to hydrolysis is a negligible factor. In addition, the inhibitors added to perchlor do not have a tendency to stain or smut polished aluminum, as do some of those added to trichlor.

"What happens to the oil and grease that is removed?" These contaminations are entirely miscible with both solvents and thus go into absolute solution with them. Most greases, oils, waxes and tallows, however, have boiling or vaporizing points well over the maximum temperatures of trichlor or perchlor, and they do not vaporize with them. As the sump solution becomes contaminated with these oils, the boiling temperature required to vaporize the solvent will increase. Thus, the amount of contamination can be measured by a simple thermometer check. It is recommended that a hydrometer be used for accuracy, and the following values illustrate the danger zone.

Oil Content %	Hydrometer Reading Trichlor	Hydrometer Reading Perchlor	Thermometer Reading Trichlor	Thermometer Reading Perchlor
0	1.46	1.61	188.8 F	249.8 F
20	1.36	1.45	193.4	255.0
***40**	**1.22**	**1.31**	**201.7**	**264.0**
60	1.12	1.18	249.0	325.0

* Time for redistillation

Redistillation of the solvent can be accomplished within the unit itself, or in separate stills, depending upon the type of equipment purchased. Most of the degreasers now manufactured have means incorporated for the recovery of the pure solvent distillate and its subsequent storage separate from the contaminated solution. Some degreasers have means of trapping the condensate in a special area which can be tapped for withdrawal of the clean solvent. Separate still and condensate recovery systems are available which permit continuous operation of the unit, by accomplishing the recovery outside the degreaser itself.

Limitations of Process

The question now arises as to what can be accomplished by vapor degreasing and just where it falls short and has to be assisted or replaced by other cleaning methods. All ferrous and nonferrous metals will condense the vapors of chlorinated solvents. Textiles may be cleaned by vapor degreasing, but excessive drag out results. Most plastics are affected by the high temperature of the solvents used, and in this instance, the lower temperatures of trichlor are more suitable, although degreasing manufacturers do not recommend their equipment for use on molded plastics, glass or rubber. Wood and wood products should never be placed in a degreaser because the essential oils will be removed. This also holds true for leather and other similar materials.

The North American Manufacturing Co. is now using vapor degreasing equipment for cleaning surfaces of pins, struts, and other small parts which are used in the industrial fuel burning equipment they manufacture. They have found that cleaning operations which formerly took from 2 to 3 hr. are now accomplished in as little as 20 min. The vapor degreasing unit they have installed holds 12 gal. of cleaning solvent and is capable of handling approximately 750 lb. of work per hr. The high boiling point of perchlorethylene makes it the chosen solvent in this case, because the majority of the parts being cleaned are small in area and cross section.

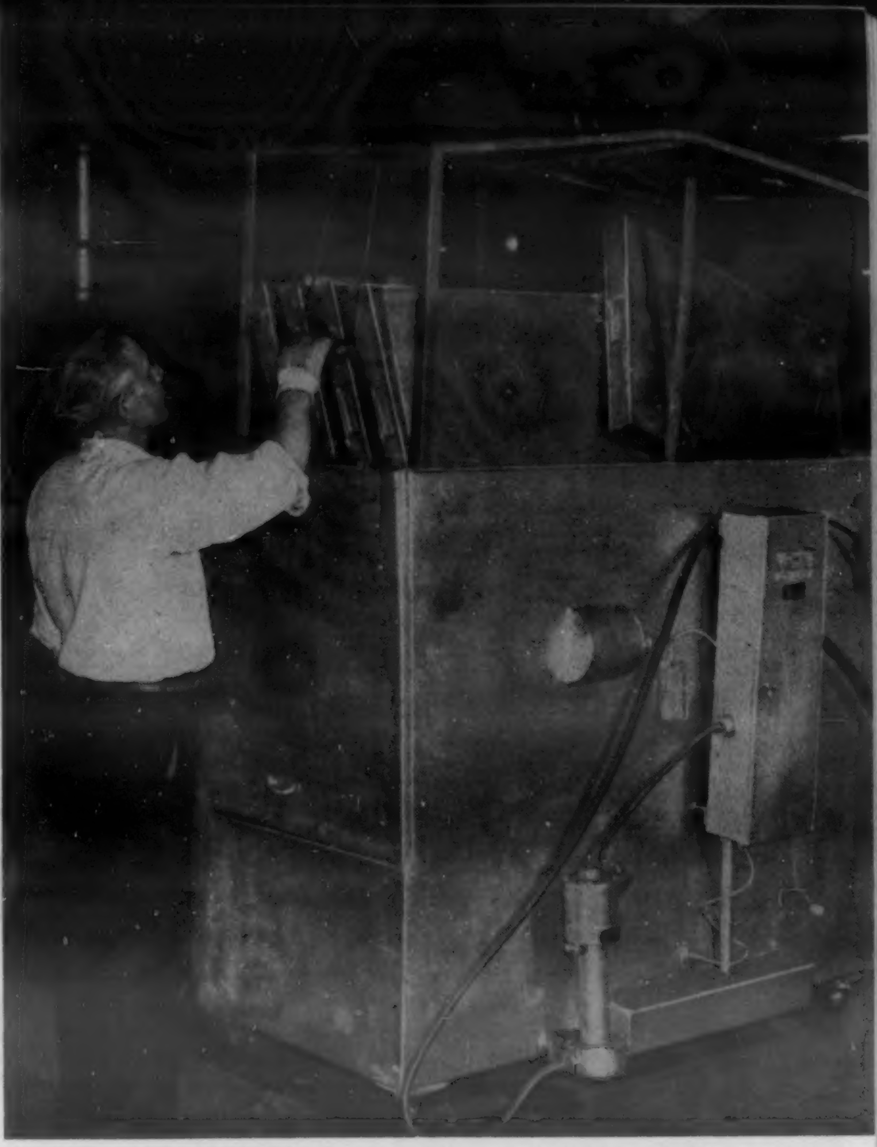
Degreasing equipment has been called upon to perform thousands of odd jobs in addition to the routine removal of grease and oil. For example, vapor degreasers are being used in gear assembly plants where press fits are required. The female section of the assembly is heated in the vapors of perchlorethylene, and then the cold shank or shaft is pressed into the expanded opening, thus insuring a tight fit. Certain types of plastics which are not harmed by the vapors of perchlor are softened for forming operations during normal degreasing. Another unusual use of degreasing units is the recovery of copper components (from electrical equipment) which have been embedded in insulating compounds. The vapors remove the insulating compound and at the same time dry the copper elements.

Vapor degreasing units are now being used for the cleaning of electric motors and motor generators. Perchlorethylene is superior to trichlor in this instance, as its higher boiling temperature completely expels any moisture from the windings and from the coils. It is imperative that motor field windings and armatures cleaned in vapor degreasers, be permitted to cool considerably before breakdown tests are attempted, as the fabric coverings on the coils will absorb some of the liquid solvent, which should be given ample time to evaporate.

Vapor degreasing will be found satisfactory for the removal of all greases, oils and waxes having a flow point below the vaporizing temperature of the solvent used. (Thus the higher vapor temperature of perchlor allows its use for a wider range of contaminants.) Its higher temperature is a definite advantage for the removal of some of the tallow animal-base fats, although, even this higher range is not always sufficient to permit successful degreasing without some assistance from coal tar or petroleum base sulphonates. Moreover, heavy deposits of grease or chips demand mechanical action in addition to solvent action. This can be accomplished through the installation of flusher pumps with hose attachments which permit momentary spraying under pressure.

Carbon Removal Difficult

The removal of carbon from metal parts has always been difficult, and degreasing manufacturers make no claims along this line for their equipment. It is true that carbon can sometimes be wiped from the surface after the grease and oil binders have been removed by degreasing. However, the removal of carbon which has been burned into the metal itself requires other treatments. Metal working plants have always experienced difficulty in the removal of graphite grease. This can now be accomplished readily by a two-stage process which includes hosing with the chlorinated solvent at a temperature of 180 F, and following this with the regular perchlor degreasing. The initial hosing removes the graphite and grease, while the subsequent vapor treatment removes any oil which may have been carried in the filtered solvent solution used for hosing.



In this rather typical vapor degreasing installation, shallow metal case are being cleaned.

Vapor degreasing, regardless of the solvent used, is not a cure-all for metal cleaning problems. For example, experience has shown that it will not do a satisfactory job in the removal of drawing and buffing compounds. In many cases a pre-dip in cool or cold solvent before the vapor phase, or a combination pre-dip and spray are needed. And in still other cases, vapor degreasing just won't work.

It can not be denied, however, that vapor degreasing is a growing process. At the present time the great variety of equipment available ranges all the way from the 20-lb., 21-in. portable unit, to units capable of degreasing a complete automobile chassis frame. The choice of the solvent as well as the choice of the equipment are problems to be discussed with degreasing engineers. Full thought must be given to the space available, the quantity of work to be handled and the nature of the work to be handled. These are not problems for salesmen to decide. Rather, when the data have been assembled, it is recommended that company engineers collaborate with degreasing engineers, so that the right unit for the job can be insured.

The Use of Ultra-Fine Particles in Powder Metallurgy

by HENRY H. HAUSNER, *Consulting Engineer*

Precise specification of metal powder size leads to uniformity of results in density, break strength, hardness and porosity of powder metal compacts.

THE EFFECT OF PARTICLE SIZE and particle size distribution on the physical properties of powder metallurgy compacts are well known and often discussed. A general rule says: "Regardless of the type of basic material, high density of the compact can be obtained with fine powders and density decreases as grain size becomes coarser—assuming other variables such as compacting pressure, sintering temperature and time, etc. remain constant." For general rules of this kind, however, there will always be exceptions and under certain circumstances the exceptions will be even the rule itself.

The particle- or grain-size in powder metallurgy is usually expressed in terms of "mesh-size" indicating thereby the results of a screen analysis. Many authors describe the powder used for powder metallurgy purposes just "as a mixture of coarse and fine particles" or as "very coarse particles" and then add the apparent density of the powder. In most references the particle size is indicated by showing the percent of powder retained on each of several mesh sizes (100, 150, 200, 250, 325) ending with some large percentage finer than 325 mesh.

This method of specifying the particle size could almost be called precise, if it would not contain this last term "minus 325 mesh size," which gives no idea at all about the actual size and distribution of the particles thus classified. Powders of −325 mesh contain particles from *1 micron* and even smaller, up to 44 microns. The actual size of −325 mesh particles depends on the processing—only very seldom will one lot of −325 mesh size particles of a certain powder be of the same size and distribution as another lot of −325 particles taken from the same powder.

It is well known that the shrinkage of powder metallurgy compacts depends on the particle size, particle size distribution, compacting pressure, pressure distribution, sintering temperature, time and atmosphere. The compacting and sintering conditions can be controlled without difficulties. The particle size and particle size distribution, however, will never be the same as long as for example, powders of −200 mesh or −325 mesh size are used. In powder metallurgy, the uniformity of production depends on the shrinkage and it is not only the author's but a general belief that the use of particles which can only be loosely defined as "−325 mesh size" is frequently the cause for the difficulties encountered with poor control and non-uniformity of shrinkage.

Libsch, Volterra and Wulff showed the effect of particle size on the physical properties of electrolytic iron compacts; for their tests they were more specific,

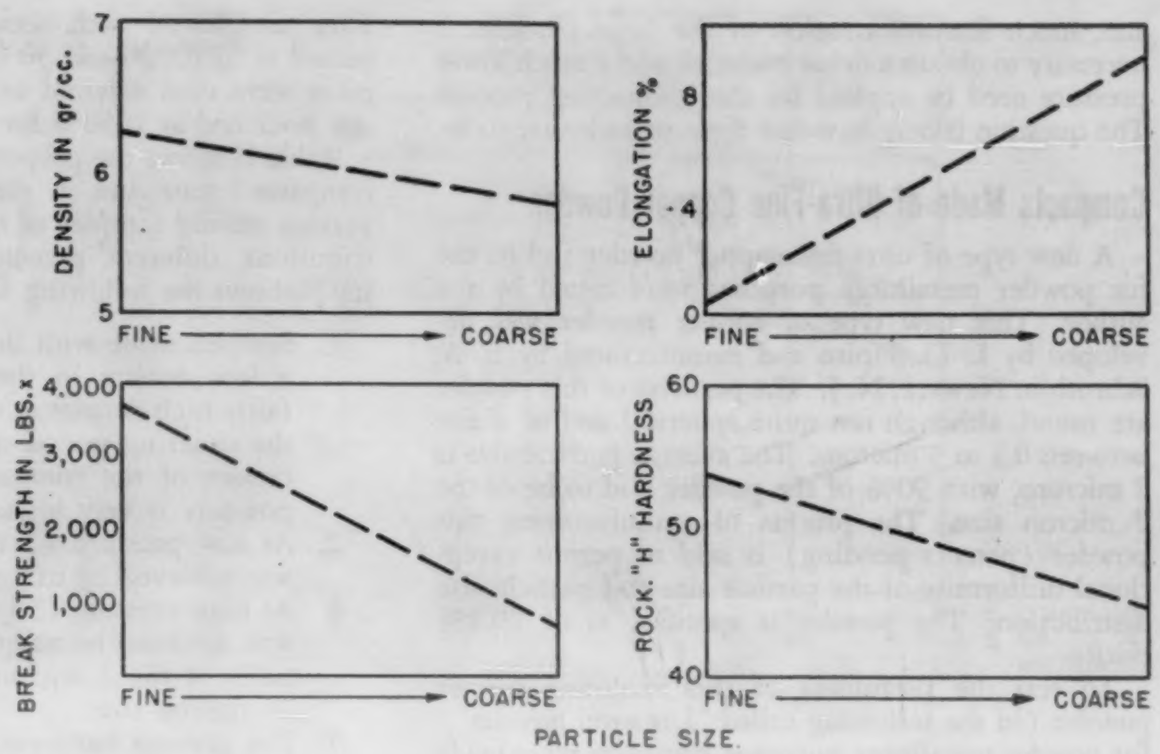


Fig. 1—Effects of particle size on the density, break strength, elongation and hardness of sintered bronze (from Baeza).

limiting their "-325 mesh size" particles to fine particles of the size -325 mesh + 500 mesh. This method of using powders of a special size is not only precise but it will always permit the duplication of the author's experiments and results.

Particle size analyses by methods depending on Stokes' law present a much more complete picture than by screening. If it were possible to make use of screens having thousands of meshes to the inch, Table I, which defines screen mesh size in terms of actual size in microns, would come into very wide use.

A typical and schematically accurate presentation of the effect of particle size on the density, break strength, elongation and hardness of a sintered material (bronze) has been given by Baeza in his book ("A Course in Powder Metallurgy," Reinhold Pub. Corp., New York) and is reproduced here as Fig. 1. The composition of the bronze was 90 parts copper, 10 parts tin, 2 parts graphite.

The fine powders were:	100% of -325 mesh size
The medium powders were:	67% of -325 mesh size
	33% of -100 mesh size
The coarse powders were:	33% of -325 mesh size
	67% of -100 mesh size

The powders were compacted at 40,000 lbs. per sq. in. Fig. 1 shows that density, break-strength and hardness decrease with increasing particle size, whereas the elongation increases under the same conditions.

Loosely heaped powder particles of spherical shape and of the same diameter will arrange themselves in different ways. Obviously, metallic powders when placed in a compacting die will fill the space only to a certain degree and a certain amount of voids will be present. It can readily be shown by a mathematical analyis that 47.7% of the apparent volume of an unpressed mass of equal-diameter spheres will be voids. To compact the powder and to eliminate or to diminish the pores of the compact, the particles have to be deformed or "worked." A fairly high pressure is necessary for this deformation of the particles.

Now, however, if the voids between the coarse powder particles are filled with powders of smaller

Table I. Micron Sizes Equivalent to Existing and (for sizes finer than 325 mesh) Hypothetical Screen-Meshes

Microns	Mesh
149	100
74	200
44	325
20	625
10	1250
5	2500
2½	5000
1	12500

size, much less deformation of the large particles is necessary to obtain a dense material, and a much lower pressure need be applied for the compacting process. The question is only how fine these particles are to be.

Compacts Made of Ultra-Fine Copper Powder

A new type of ultra-fine copper powder and its use for powder metallurgy purposes were tested by the author. This new type of copper powder was developed by L. D. Supiro and manufactured by E. A. Schroth in Newark, N. J. The particles of this powder are round, although not quite spherical and of a size between 0.3 to 3 microns. The average particle size is 2 microns, with 90% of the powder said to be of the 2 micron size. The process of manufacturing this powder (patents pending) is said to permit exceptional uniformity of the particle size and particle size distribution. The powder is specified as of 99.4% purity.

To test the usefulness of this ultra-fine copper powder (in the following called "2 micron powder") for powder metallurgy purposes, compacts were made with this powder and compared with compacts made from electrolytic copper powder of 200 to 325 mesh size (in the following called "44 to 74 micron powder") and also with mixtures of different particle sizes.

The following four test series will be described in detail:

Series A:	2 micron powder	100%
Series B:	44 to 74 micron powder	100%
Series C:	2 micron powder	47%
	44 to 74 micron powder	53%
Series D:	-325 mesh powder	47%
	44 to 74 micron powder	53%

Four samples of each series were made and compacted at 5, 10, 20 and 30 tons per sq. in. The compacts were then sintered in hydrogen at 1475 F for one hour and at 1650 F for one more hour.

Table II shows the properties of the samples in the compacted state and in the sintered state. A comparison among samples of different particle size distributions, different pressures and in the different states shows the following facts:

1. Samples made with the 2 micron powder show a low density in the compacted state and a fairly high density in the sintered state. During the sintering period the percentage density increases of the compacts made from ultra-fine powders is very high.
2. At low pressure (5 t.s.i.) the highest density was achieved by using the 2 micron powder.
3. At high pressure (30 t.s.i.) the greatest density was achieved by using a mixture of 47% particles of the 2 micron size and 53% of 44 to 74 micron size.
4. The greatest hardness was achieved with samples made entirely of the 2 micron powder.
5. There is no great difference in density between samples made of the 2 micron and 44 to 74 micron mixture and the samples of the -325 mesh size and 44 to 74 micron mixture. The density of samples made with the 2 micron particles is slightly greater. The hardness of the samples with 2 micron particles is remarkably greater than the hardness of the samples made with -325 mesh size particles.

The effect of copper particle size distribution and compact pressure on the density of the copper compacts is shown graphically in Fig. 2, which was pre-

Table II. Properties of Pressed and of Sintered Copper Compacts made From Different Particle-Size Mixtures

			Properties				
			After Pressing		After Sintering		
Sample Number	Particle Size Distribution	Pressing Pressure t.s.i.	Volume, cc	Density, g/cc	Volume, cc	Density, g/cc	Hardness, Rockwell H
A 1	100% 2 microns	5	2.99	4.95	1.92	7.72	29
2		10	2.69	5.54	1.91	7.80	38
3		20	2.38	6.29	1.89	7.95	51
4		30	2.08	6.94	1.76	8.18	61
B 5	100% 44 to 74 microns	5	2.77	5.38	2.26	6.58	<1
6		10	2.40	6.07	2.06	7.04	12
7		20	2.15	6.88	1.93	7.67	31
8		20	1.91	7.65	1.83	7.98	42
C 9	47% 2 microns; 53% 44 to 74 microns	5	2.74	5.48	2.10	7.15	23
10		10	2.84	5.47	2.06	7.48	36
11		20	2.12	6.89	1.81	8.05	47
12		30	1.95	7.64	1.74	8.45	54
D 13	47% -325 mesh; 53% 44 to 74 microns	5	2.74	5.40	2.09	7.10	20
14		10	2.56	5.71	1.98	7.37	33
15		20	2.24	6.82	1.83	7.99	43
16		30	1.96	7.66	1.80	8.31	52

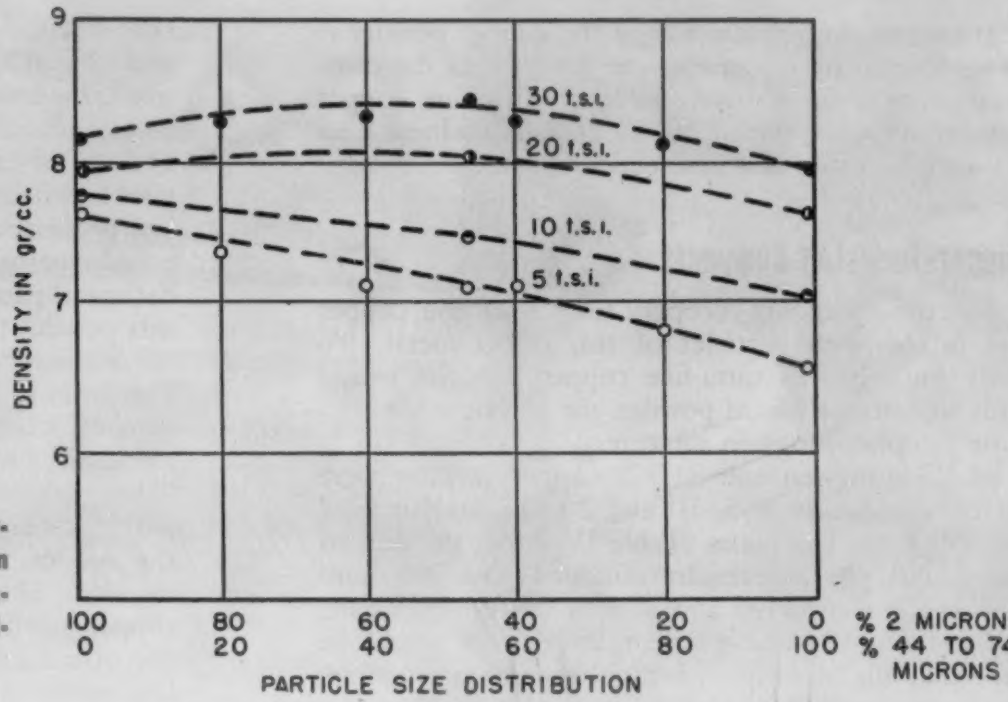


Fig. 2—The effect of particle size distribution on the density of copper compacts, compacted at various pressures.

pared from the data in Table II, plus the results of tests made with a few samples of different mixtures of the 2 micron powder with the 44 to 74 micron particles. Fig. 2 shows that the theoretical calculation mentioned before, indicating that somewhat less than 50% of the volume of a compact is initially voids that must be filled with fine particles to achieve a maximum density, holds true only in cases where a fairly high pressure (30 t.s.i.) is used for compacting. The percentage of fine particles must however, be increased when it is desired to use lower pressures for compacting purposes.

Copper-Tin Compacts

In two other test series the effect of particle size on the properties of a mixture of 90% copper and 10% tin was determined. Table III shows the dimensional and physical results obtained with a copper-tin mixture of copper particles of the 2 micron size and also with particles of the 44 to 74 micron size, in the compacted and also in the sintered state. The samples were compacted at 5, 10, 20 and 30 t.s.i., sintered in hydrogen at 1475 F for 1½ hours.

This table also shows that in the compacted state the densities vary with the compacting pressures, whereas in the sintered state the compacting pressure is of practically no influence on the density. Table II shows further that the particle size distribution is of no substantial influence on the density, although the samples made with ultra-fine copper particles are of slightly greater density.

Table III. Effect of Particle Size on the Properties of Pressed and of Sintered 90/10 Copper-Tin Bronze

Sample No.	Powders and Particle Size Distribution	Pressing Pressures t.s.i.	Properties: After Pressing: Volume, cc	Density, g/cc	After Sintering: Volume, cc	Density, g/cc	Hardness, 15 T
17	Copper, 2 microns; Tin, 44 to 74 microns	5	2.45	5.06	1.97	6.24	26
18		10	2.04	5.75	1.86	6.24	
19		20	1.84	6.52	1.86	6.34	
20		30	1.67	7.01	1.81	6.40	33
21	Copper and tin 44 to 74 microns	5	2.07	5.90	1.98	6.12	14
22		10	1.86	6.45	1.92	6.18	
23		20	1.70	7.25	1.99	6.13	
24		30	1.57	7.65	1.99	6.04	17

However, the particle size of the copper powder *is* of substantial importance to the hardness of the compacts; copper-tin samples made of ultra-fine copper powder show an almost 100% greater hardness than the samples made of coarse copper powder.

Copper-Tungsten Compacts

For the foregoing (copper-tin) tests the copper was mixed with particles of tin, a soft metal. To study the effect of ultra-fine copper particles mixed with an extremely hard powder, the author made tests with a copper-tungsten mixture.

18.3% tungsten and 81.7% copper powder were mixed, compacted at 5, 10 and 20 t.s.i. and sintered at 1650 F for 1½ hours. Table IV shows the dimensional and physical results obtained with the samples in the compacted and also in the sintered state, using different particle-size mixtures. As would be expected, the densities of the sintered samples are much greater when ultra-fine copper powders are used. Furthermore, after sintering a decrease in density occurs when coarse particles are compressed at higher (20 t.s.i.) pressure. Again, the hardness of the samples made with ultra-fine copper particles is much greater than the hardness of the samples made with coarse copper particles.

In general, the compacts made of −325 mesh size tungsten particles show lower densities than the samples made of coarse tungsten particles. However, samples Nos. 31 to 33, made of −325 mesh size tungsten and 2 micron copper powder show the highest hardness figures.

Conclusions

From these tests it can be said that it is advantageous in many cases to use ultra-fine copper powders for powder metallurgy purposes. The following specific conclusions may be drawn:

1. The described type of ultra-fine powder is of greater uniformity than the various "−325 mesh size" powders, and its use will guarantee also a greater uniformity in shrinkage of the compact.
2. The use of ultra-fine copper powder seems advisable where high densities are sought, using low pressures. The use of the 2 micron copper powder permits the manufacture of larger powder-metal parts than heretofore because by using this powder the pressure applied to the unit of the surface can be kept low.
3. The ultra-fine copper powder is also advantageous where maximum hardness and high mechanical strength are desired.
4. Where copper is to be mixed with very fine particles of other materials, such as graphite, the use of ultra-fine powders can be recommended. The great mixability of the 2 micron copper powder with other fine powders permits the manufacture of compacts possessing excellent structural uniformity.
5. The flow of ultra-fine powders is generally poor. However, mixtures of the 2 micron copper powder with large particles such as described above for the different test series show good flowing qualities. For the manufacture of larger parts made entirely of ultra-fine copper powder, the flowing qualities are of less importance and can easily be improved by mechanical means.

There is no doubt that the advantages of the ultra-fine copper powder will be useful in powder metallurgy. Intelligently applied, 2 micron copper powder will permit the manufacture of products of better physical properties and of greater uniformity than before.

The samples and tests described in this report were made in the Powder Metallurgy Laboratory of New York University. The author wishes to thank the Research Department of New York University for use of the laboratory.

Table IV. Effect of Particle Sizes on the Properties of Copper-Tungsten (81.7% Copper, 18.3 Tungsten), As-Pressed and After Sintering

Sample No.	Powders and Particle Sizes	Pressing Pressures t.s.i.	Properties: After Pressing: Volume, cc	After Pressing: Density, g/cc	After Sintering: Volume, cc	After Sintering: Density, g/cc	After Sintering: Hardness, Rockwell H
25	Copper, 2 microns; tungsten, 44 to 74 microns	5	3.07	6.42	2.25	8.75	48
26		10	2.62	7.50	2.21	8.90	57
27		20	2.38	8.54	2.22	9.07	67
28	Copper and tungsten, 44 to 74 microns	5	2.80	7.04	2.47	7.97	24
29		10	2.42	8.25	2.30	8.65	38
30		20	2.16	9.25	2.40	8.30	40
31	Copper, 2 microns; tungsten, −325 mesh	5	3.08	6.33	2.30	8.40	51
32		10	2.75	7.20	2.28	8.59	54
33		20	2.21	8.24	2.03	8.94	59
34	Copper, 44 to 74 microns; tungsten, −325 mesh	5	2.94	6.82	2.67	7.30	14
35		10	2.42	7.88	2.29	8.25	31
36		20	2.22	8.78	2.19	8.80	41

This small press is capable of producing up to 1200 brass forgings per hr. Furnace at left is an automatic type delivering heated slugs at required speed. Any slugs not used are discharged into a tote box and reheated later.

Extruded Shapes Speed Brass Forging Output

by HERBERT CHASE

Manufacture of brass and bronze press forgings at Titan Metal Manufacturing Co., greatly expanded by war requirements, promises to continue at a corresponding rate. Output in the two adjacent plants of this company approximates 20% of the national output of brass forgings, and is, perhaps, the largest of any one maker. Current production is close to war peaks and may exceed these as new dies, now starting to come into use, become available.

To date, brass forgings ranging from 1/4 oz. to 30 lb. have been turned out. But presses and furnaces recently installed have capacities for making forgings weighing up to 100 lb., hence forgings of unusually large size for copper base types can be anticipated.

Since press forgings are made, of course, from slugs cut from bars and shapes, Titan is fortunate in having its own extrusion facilities in the same plants. Nearly all forgings are produced in a single stroke of the press and the flow of metal to fill the dies can be greatly facilitated if the slugs are so shaped that the metal has only a short distance to flow. For this reason, special extruded shapes are often made to the general contour of the forging die cavity. Occasionally, slugs are first upset in one die and later are transferred, after reheating, to the final forging die.

In general, forging rates range from 100 to 1200 per hr. but, for the higher rates, as many as three men per press are needed, one feeding the furnace, one operating the press, and one to eject the forgings. More often, one pressman and a furnace man are sufficient and the furnace man frequently can feed slugs to two or more furnaces supplying as many

Slugs so shaped that metal has only a short distance to flow facilitates production of a variety of brass parts with one stroke of forging presses.

Charging a heating furnace with slugs. Many slugs are cut from special shapes. Those shown here have a U-shaped section.

presses. Most of the furnaces used are designed and built especially for the job by Titan although some components, such as oil burners, pyrometric controls and conveyors are more or less standard items. Nearly all furnaces have automatic controls so arranged that slugs issue at the required rate and at correct forging temperature without remaining so long in the furnace as to yield excessive grain size.

Several types of forging presses are in use but a considerable proportion, including all of large size, are late designs of National, Bliss and Clearing makes. Older presses include several of Titan design in which the lower platen is elevated by a cam or eccentric on a flywheel driven by gearing. There is also one Zey & Hanneman screw-type percussion press having a horizontal flywheel connected by a clutch at the top of the screw.

Production in the forge shop starts with cutting slugs from bar stock and from extruded shapes on fast circular saws of high speed steel. Several such saws are used, each being fed with stock advanced by hand to a stop, along a roller table. Cuts are made under a stream of coolant and are about 1/8-in. wide. Slugs fall into tote boxes for removal to furnaces.

Small Fittings

Typical of high speed production is that of small fittings on a Maxipress, using slugs of roughly U-shape or channel section. These are fed onto the belt conveyor by hand, each slug being placed so that it issues at the press in a position most convenient for the press operator to pick it up with tongs and place the slug in correct position in the lower die cavity.

As soon as his tongs clear the die, the operator trips the press. This closes and immediately opens the die, at the same time operating the knockout. While the operator reaches for the next part, another man back of the press uses tongs to lift the forging free and drop it into a chute down which it slides into a tote box. This second man also lubricates the die and performs rough inspection. He can stop the press in the event that rejects are produced.

In such a setup, three men, including the one charging the furnace, act as a team and produce about 1200 forgings per hr. All three men are trained to do all three jobs, receive the same pay and change places from time to time. This has been found to make for rapid and economical work.

The furnace used in this setup has the conveyor set, of course, to deliver slugs at the required rate and the Leeds & Northrup controls adjust oil flow to the burners so that slugs issue at forging temperature, usually 1,350 to 1,400 F. Timing is such that slugs are not kept too long at this temperature. In the event that die or other trouble causes the press to be shut down, heated slugs fall into a tote box at the exit end of the conveyor where they remain until cool. When these slugs are again fed through the furnace, the cycle time is changed somewhat so as to allow for the change in grain size in the first heating.

Efforts are made to keep flash as thin as feasible and still prevent flaws that might result if the flash is too thin. Flash sometimes shows cracks, especially

Brass forgings as they appear before flash is removed and, beside each, the slug from which the forging is made. When slugs approximate the finished shape of the forging, less flow of metal is required in the forging operation.

Same forgings shown in previous illustration as they appear from the reverse side. Ribs, bosses and recesses, some of the latter for metal saving purposes, are worthy of note.

where quite thin, and care has to be exercised to see that these flash cracks do not extend into the forging itself.

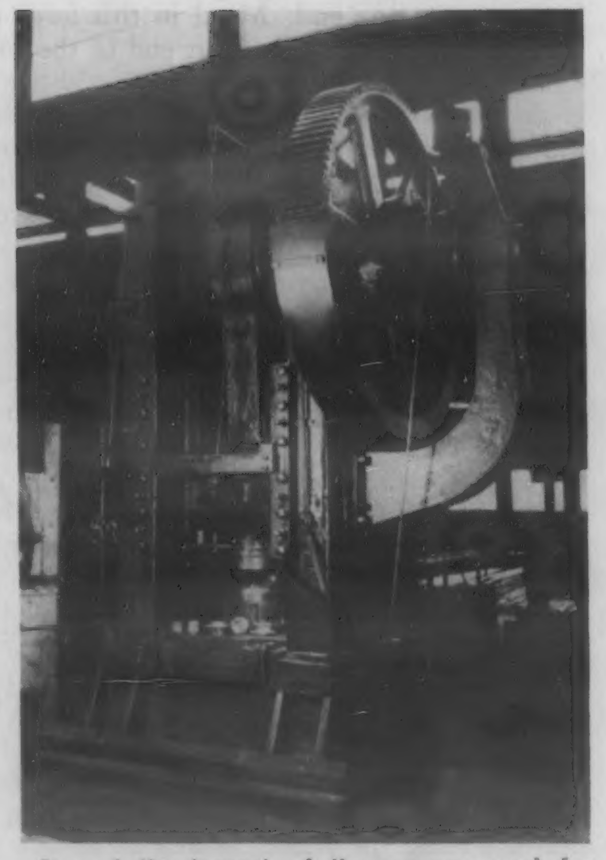
Many forgings, especially those of generally circular shape, are made from cylindrical slugs cut from round extruded bars. This is true, for example, for certain hose couplings. Some parts of this type are among those produced in the Bliss press. A forging that is hollow, has two steps, measures about 4-in. in diameter and is about 5-in. in axial length is typical of forgings readily made in this press.

Such forgings can be made at about 300 to 400 per hr. with one pressman and one man giving part or full time to loading the furnace. The fairly large blanks needed in this case are often fed through the furnace in trays having intermittent hand or pusher feed. Dies have knockouts and the pressman lifts the part free and drops it in a tote box before taking the next slug from the furnace.

A still larger Bliss press is employed for making such forgings as one which measures about 7-in. across the flange and is hollow. It is formed from a cylindrical slug of about 4-in. diam. and nearly the same height. In forging such a part, the metal is forced upward around the punch and also outward to form the flange.

Produce 100-lb. Forgings

In the largest Maxipress, which is of 2,500-ton capacity, forgings up to 100-lb. in weight can be produced. However, the press is used, far below capacity,



One of the largest of the presses used for making heavy brass forgings such as are seen on the platen in front of the forging die.

This 2,500-ton press can make brass forgings weighing up to 100-lb. but is used mostly for much lighter forgings (still classed as heavy, for brass) of fairly large area, using slugs from pusher furnace at left.

for forging a hinge part having two heavy lugs at the wide end. This forging is made from a bar slug first upset at one end. Metal in this large end helps to form the heavy lugs at that end of the forging.

The rate on this forging is about 300 per hr. which is as fast as one operator can handle the slugs into the die and remove the forgings. Slugs are fed through the furnace in trays that are advanced by a hydraulic pusher in three rows. A Hauck oil burner supplies fuel under automatic thermostatic control. Because of the large size of slugs, heating is comparatively slow, hence the wide furnace arranged for handling three rows of trays at once.

One of the relatively small Titan presses has a fixed upper platen and a lower platen that is lifted by an eccentric to perform the forging operation. In this case, the forging dies upset a flange at the center of a valve stem after which the stem is straightened and planished between a pair of slotted plates in a planer seen in the right foreground.

One man performs the complete set of operations at the rate of about 100 pieces an hr., including the tending of the furnace. Slugs are cut from round bars and, as only the portion to be upset has to be heated to forging temperature, a hand fed slot furnace is used. Slugs are laid across the slot on top of the furnace and are heated over a length about equal to the slot width by the flame issuing from the slot. The operator adds a new slug for each one taken off and, in this case, judges, largely by color, when the slug is up to forging heat.

To upset the flange, the operator inserts one end of the slug into a hole in the lower portion of the die and trips the press. This applies pressure to both ends of the slug and upsets the heated portion to fill the cavity left for this purpose, thereby forming the flange. An ejector frees the forging and it is lifted out and then is laid with tongs so that the flange rests in the slot of the planishing plates between which the stem is rolled and straightened.

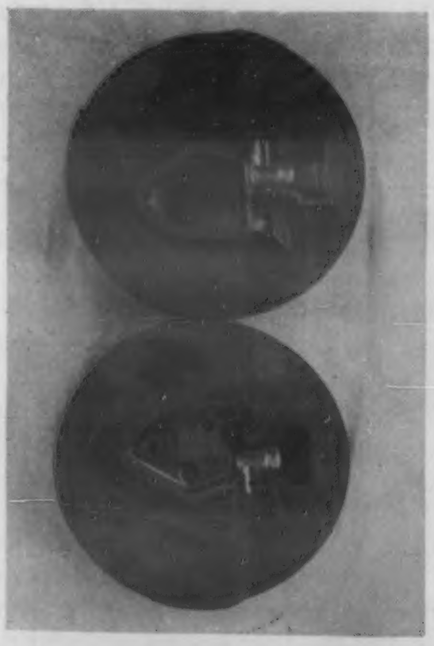
Although this is not a very rapid cycle, it yields a forging of the required dimensions, properties and grain structure. There is, of course, a large saving of metal over that which would be required if the part were to be turned from a bar of flange diameter, besides which a stronger product is attained. Planishing holds the stem within close dimensions and results in a very smooth finish thereon.

For some small forgings that are best made with a steady pressure applied somewhat more slowly than in other types of presses used in this shop, the screw-type percussion press serves well. It is used, for example, to form, from a cylindrical slug, parts with a small central boss and large thin flange. This operation is not so fast as some others but produces desired results.

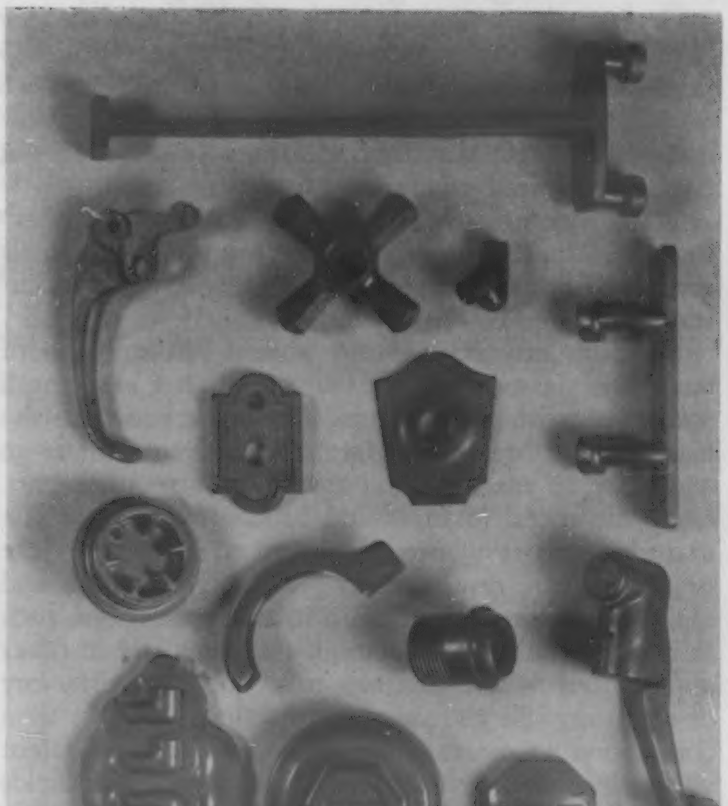
All forging dies used in this plant are cut from hot-worked heat resistant steel. As forging temperatures are moderate and the metal forged is not long in contact with die surfaces, fairly long die life results.

Dies do not require water cooling. In fact, where operation is slow, it sometimes is necessary to supply heat from a gas burner to keep the die at desired forging temperature. Lubrication with Oildag or Hough-

Planishing stems of brass valve forgings having a central flange upset in the press in background. Part of slug to be upset is heated over a slot in top of furnace at left.



Fairly typical forging die for a small brass part that involves integral fittings later drilled out.



Variety of small brass forgings fairly typical of Titan production. Several are hardware parts and others are for pressure fittings, plumbing, etc. Elbows, bottom right, shown before flash removal, are unusual in that they are produced in a four-cavity die.

Composition and Properties of Brass Forging Alloys

Composition (nominal) %	Yellow Brass ASTM-B-124-44 No. 2	Naval Brass Navy Spec. 46-B-6-Int	Leaded Naval Brass ASTM B-21-44 Grade B	Redaloy	Nickel Silver Tinicosil No. 53	Mang. Bronze 46-B-15 Class A	Mang. Bronze Ams. 4619	Aluminum Bronze
Copper	58.5 - 60.5	60	60	54	46	59	58	Rem.
Silicon								1.6 - 2.5
Lead	1.50-2.50	—	0.80	3.0				
Tin		0.75	0.75			0.75		
Nickel					10			
Iron						1.00	1	
Manganese						0.40	0.50 max.	
Aluminum							1	6.5 - 80
Zinc	Rem.	Rem.	Rem.	Rem.	Rem.	Rem.	Rem.	—
Tensile strength psi.	57000	60000	60000		98000	68000	70000	90000
Yield strength psi.	32000	28000	30000		65000		30000	45000
Compressive strength psi.	85000							
Shearing strength psi.	55000							
% elongation in 2 in.	32	40	40		22	33	20	
Reduction of area %	33							30
Rockwell Hardness B	55 - 60	55	55			70		85
Brinell Hardness	94					130		
Melting Point deg. F	1620							
Specific Gravity	8.40							

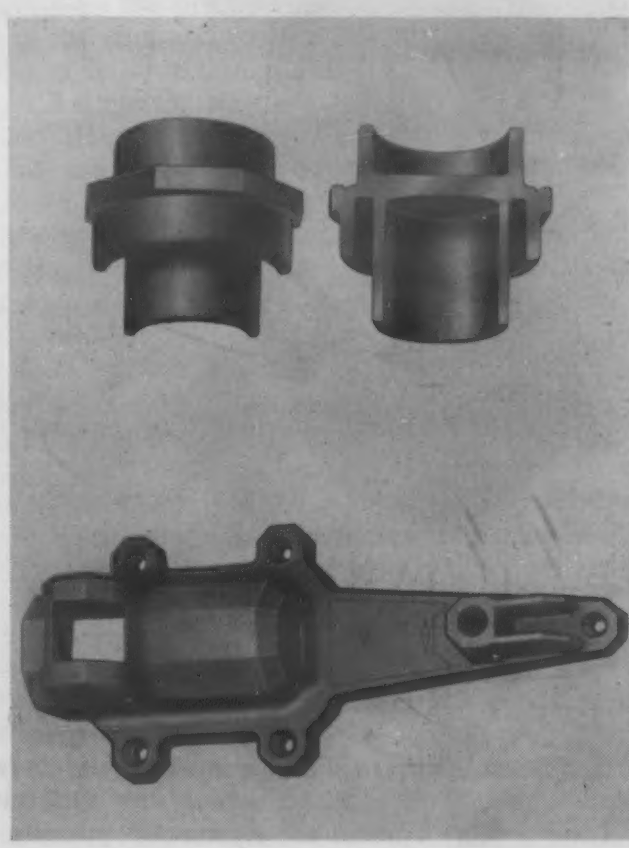
ton's hotworking lubricant helps to prevent forgings from sticking in the die as well as to minimize die wear.

Illustrations give a good idea as to the types of parts forged. A large proportion of these are for hardware, plumbing, valves, fittings, home appliance parts and the like. Surfaces are smooth enough to require little or no preparation for finishing and dimensions are usually close enough so that only light cuts are required where machining is needed.

Flash is commonly removed by a shearing or shaving die. When required, forgings are pickled in nitric acid and thoroughly rinsed. This gives them an attractive golden color.

Forgings are available in several alloys, some of which are classed as bronzes and are higher in strength and in certain type of corrosion resistance than the usual yellow brass. The latter, however, is lower in cost, easy to machine and meets most requirements.

As the metal in brass and bronze forgings is first extruded and is worked again when forged, a close grain structure results. This yields high strength and makes forgings well suited in many applications, such as non-porous fittings for high pressures and in other applications where castings may not be satisfactory or so strong. In general, brass forgings cost less than corresponding die castings in the same or equivalent alloys, but both types of product have useful fields of application and each can be made in some forms that cannot be duplicated by the other process. An accompanying table gives the physical properties of the alloys commonly employed in copper base forgings.



Two somewhat difficult brass forgings, one being a hardware part and the other, shown cut longitudinally, illustrating how punches can form cylindrical and annular recesses.

Rectification of High Temperature Salt Baths

by ROBERT S. BURPO, JR., *Associate Editor*, MATERIALS & METHODS

IT WAS THOUGHT that the use of neutral salt baths for hardening steels would solve many problems, especially in the hardening of tool and high speed steels. Immersed in a molten, neutral salt bath, the work-pieces would be heated more uniformly and with less thermal shock than in any other type of furnace; the molten salt would freeze onto the surface of the cool steel as it was introduced into the bath forming an insulating layer that would melt slowly, allowing the work-piece to be warmed gradually and evenly. Theoretically, when the tool or die was submerged in the salt bath it could neither carburize nor decarburize as the salt was neutral and the work-piece was not in contact with the air. Another advantage of the molten salt was that a thin film would adhere to the hot work-piece as it was withdrawn from the bath, thus protecting it from sealing in the air as it was carried to the quench or allowed to air harden.

These improvements and advantages were all real except the expected lack of effect of the neutral salt on the surface of the hot steel. High speed steel tools tended to have a scaley and decarburized surface after being hardened in a neutral salt bath.

Why? Partially because the chemistry of iron refining is reversable. Iron ore (iron oxide) is reduced to pure iron with the aid of high temperature generated by burning coke in a blast furnace—the carbon from the coke combines with the oxygen in the iron ore to form gaseous carbon dioxide, leaving the iron behind. This reaction was taking place in reverse in the salt bath: the carbon in the surface of the hot steel work-piece (present in the form of iron carbide) combined with some active oxides in the bath to create carbon dioxide, leaving carbon-free iron and perhaps some iron oxides (or scale) on the surface. Since both iron and iron oxides are useless as tool materials, decarburization of high speed steels (and other tool steels requiring a high hardening temperature—such as high carbon, high chromium die steels) was still to be guarded against even when hardening in a neutral salt bath.

A neutral salt bath, for example, would be barium chloride which melts at about 1750 F and would neither carburize nor decarburize tool steels when molten. After about 100 hr. of operation a molten salt bath of this type contains an appreciable percentage of oxides (iron oxides from the pot and nickel oxides from the electrodes). These iron and nickel oxides are highly active at the temperatures used for the hardening of high speed steels (2200 to 2400 F). It is when the soluble and the insoluble oxides exceed 3% and 5%, respectively, that the decarburization of the work-pieces becomes dangerous; and these concentrations are obtained after 100 or 750 hr. of operation depending upon whether an iron or ceramic pot is used. (If an iron pot is used, objectionable concentrations of oxides build up after 100 hr. of operation; if a ceramic pot is used, the time is lengthened to about 750 hr. before the oxide content of the bath becomes excessive.) It is these oxides that combine with the carbon from the surface of the hot steel, causing decarburization.

Self-Rectified Salt Bath

The self-rectified salt bath was developed as an answer to this decarburization problem. Silica (silicon dioxide or quartz sand) was added to the salt bath as the rectifying agent. Amounts varying from 2 oz. to a pound or more per day were used to rectify salt baths. This agent combined with the oxides to form a sludge that collected at the bottom of the pot.

While partial rectification was achieved by this expedient, two other detrimental actions occurred as a result of its use: the sludge was difficult to remove from the bath, and it attacked the electrodes, seriously reducing their useful life. If these rectification difficulties could be overcome, the salt bath would be the ideal medium for hardening many tools and dies because its advantages would then far outweigh its disadvantages. No other hardening medium could offer the versatility, the uniformly clean and unaltered hardened surface, and the desirable thermal characteristics of a molten salt bath.

Graphite Rod Rectified Salt Bath

Because of the favorable potentialities of the salt bath method of batch type heat treatment, a study of the chemistry of the bath has been made and, as a result of this study, a rectified high-speed-steel-hardening salt bath has been developed.

High temperature salt baths have a tendency to decarburize steel surfaces, thus means should be taken to help the bath to keep neutral.

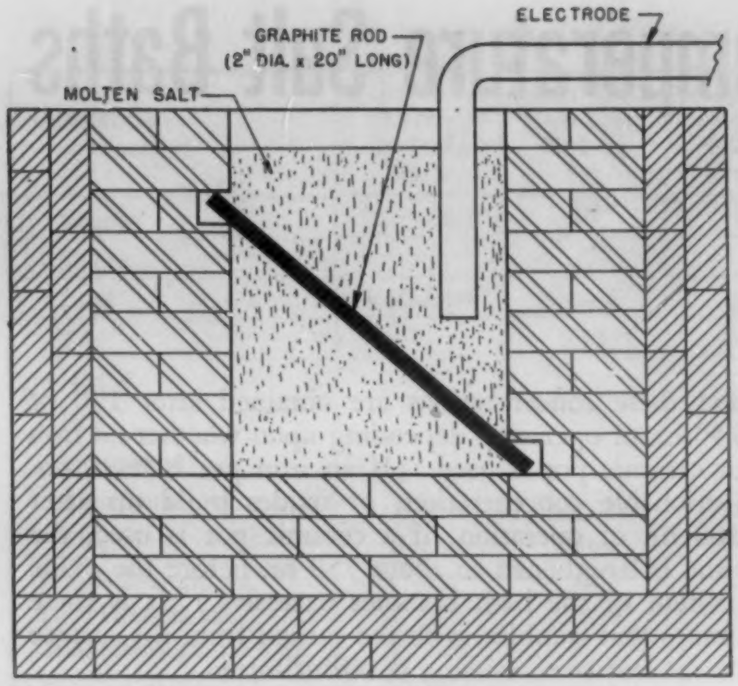


Fig. 1—In placing a graphite rod in the salt bath it is anchored in such a way that it will be out of the way of the work.

Simplicity is one of the virtues of this rectified bath. A schematic cross-section of the furnace showing the location of the graphite rod is given in Fig. 1. The furnace is a rectangular pot, immersed electrode type, having a graphite rod submerged in the molten salt; this graphite rod furnishes the needed rectification. Because this rod is lighter than the liquid salt, a means of anchoring it had to be devised where it would not contact the work and where it easily could be replaced. For holding the rod, two small holes, each 2-in. square by 2-in. deep, were cut in the sides of the ceramic pot; one of these holes was in the back of the pot, at the lower right hand corner, and the other was in the front, at the top right hand corner. Thus the graphite rod was held at an angle in the bath and its buoyancy acted to keep it in place.

It was the action of the graphite rod that rectified the liquid salt. The graphite rod, being carbon, could furnish the necessary carbon to reduce the objectionable oxides in the bath, thus preventing the use of the carbon from the steel. Proof of the action of the rod is obtained when it is removed from the bath and scraped to remove the agglomerated "slag". A large proportion of the adhering particles are found to be attracted by a magnet (hence they are particles of iron showing that the oxides in the bath have been reduced to iron by the carbon in the rod, and that this iron has been deposited on the rod). In addition, there is little or no sludge deposited in the bottom of the bath nor is the surface of hardened work discolored or decarburized when a graphite rod is submerged in the salt bath. The operating characteristics of the non-rectified, the silica rectified, and the graphite rod rectified salt baths are summarized in Table 1 and Fig. 2.

Table 1 — Operating Characteristics of Non-rectified and Rectified High Temperature Salt Baths

Rectifier	Operating Temperature	Average Electrode Life	Remarks
None	2225 F	2650 hr.	The same furnace can be used with any of these salt baths, and the same salt can be used in all three
2 oz. silica every 24 hr.	2225 F	720 hr.	
Graphite rod	2225 F	4000 hr.	

Operation of a Rectified Salt Bath

One factory uses a rectified high temperature salt bath for hardening tools and dies made of high speed and high carbon, high chromium steels. The heat treating cycle employed is as follows:

Operation	Medium	Temperature range, deg. F
Preheat	Neutral salt bath	1400-1800
Harden	Neutral rectified salt bath	1700-2400
Quench	Neutral salt bath	1050-1500
Air Cool	———	———
Temper	———	as desired
Subzero treatment	Mechanical refrigeration	to −120 F
Retemper	———	as needed

The salt mixture used for hardening is largely

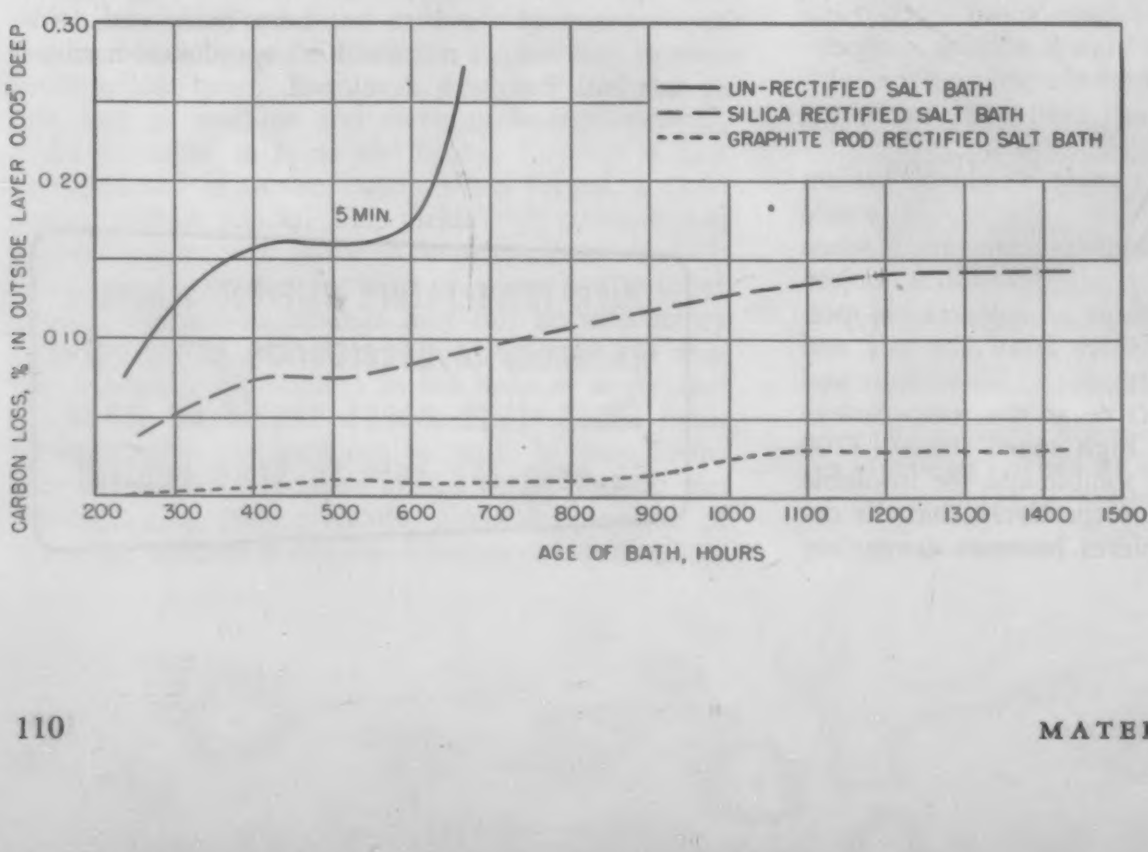


Fig. 2—Operating characteristics of non-rectified, silica rectified and graphite rectified salt baths.

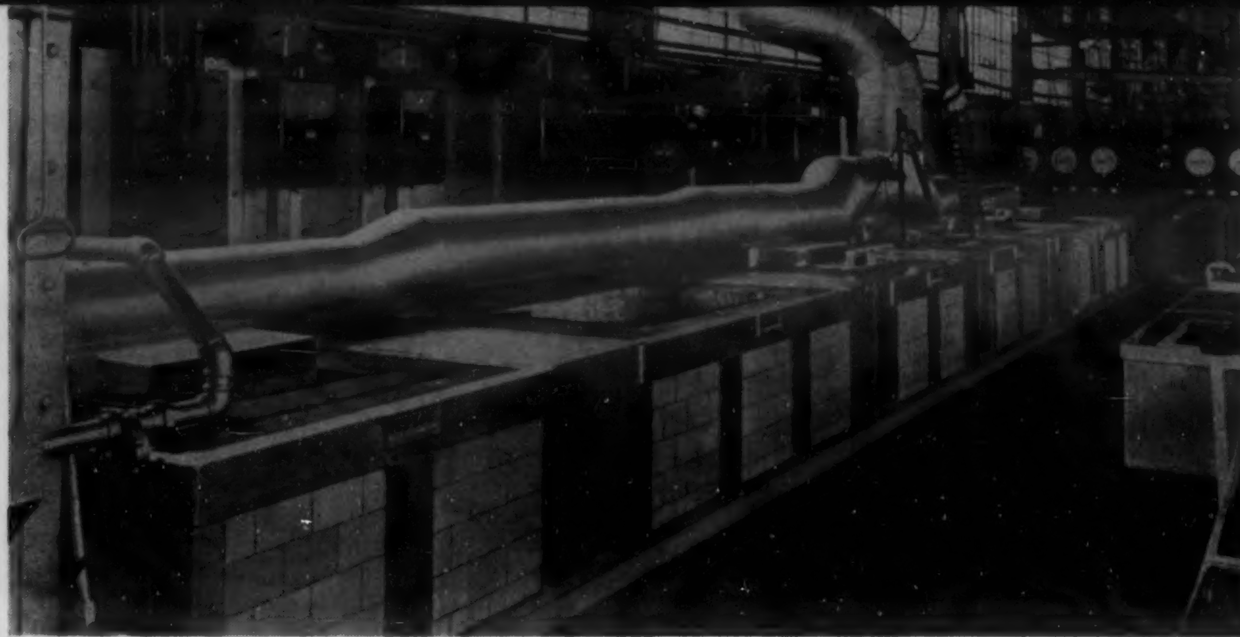


Fig. 3—This is a general view of the salt bath department of The Dayton Forging and Heat Treating Co.

anhydrous barium chloride with a small percentage of other salts added to lower the melting point so that the minimum operating temperature is about 1700 F (pure barium chloride melts at 1750 F).

The graphite rod is removed from the salt bath after three hours of operation and replaced by another. When the used rods are cooled, they can be scraped free of sludge. Each rod has a useful life of a week to ten days and costs about fifty cents.

This practice of operating the salt bath with the rectifying rod in place during the hardening operation is not universal. The conveyorized automatic heat treating salt bath equipment used for hardening high speed steel bevel gear cutters at the Gleason Works, Rochester, New York, is rectified by constant immersions of the graphite rods. It was the former practice at Gleason to put the rectifying rod in the bath only during the warming up period at the beginning of the day's work and again during the inactive period at lunch time.

The Gleason installation is made up of four individual salt baths. The first is a preheat, the second is the high heat (or hardening) bath, the salt bath quench is third, and the fourth is the tempering bath. The work passes through the first three salt baths on an automatically timed conveyor. The quenched workpieces are taken from the conveyor and loaded into a basket manually. This basket load of hardened tools is then washed, dried, and placed in the fourth bath for tempering. The hourly capacity of this salt bath hardening unit is approximately 300 lb.

Rectified Salt Bath at Dayton Forging and Heat Treating Co.

A Dayton, Ohio organization that has done considerable experimental work with rectified salt baths, is the Dayton Forging and Heat Treating Co. This is a job shop that handles a wide variety of heat treating operations. A view of the salt bath arrangement in this shop is given in Fig. 3.

When these new furnaces (shown in Fig. 3) were installed and for the first nine weeks of their operation, Irvin H. Schaible, chief metallurgical engineer, used a carbon rod to rectify the high temperature bath. The rod created considerable turbulence in the bath and apparently was reducing some of the oxides, as a magnetic sludge was recovered from the bottom of the pot, but there was little or no pick-up on the carbon rod. Sludge removal operations were carried out regularly yet trouble developed before long with a decarburized surface appearing on the work.

As a remedy, the carbon rod was replaced by one of graphite. The turbulence of the bath was reduced. And the bath was operated at heat (but with no work in it) for 16 hr. before the precipitation of metal on the rod was completed. This precipitation on the rod continuing for 16 hr., even though there was no work in the bath, indicated that the previously used carbon rod had not been giving satisfactory rectification. The two heat treating cycles of the Dayton Forging and Heating Co. employing this rectified salt bath are:

High Speed Steel Hardening	High Carbon High Chromium Steel Hardening
Preheat at 1100 F	Preheat at 1100 F
Second preheat at 1550 F	Second preheat at 1450 F
Harden at 2200 to 2400 F	Harden at 1725 to 1875 F
Quench into salt at 1100 F	Quench into salt at 1100 F
Cool in oil or air	Cool in oil or air
Double temper	Single or double temper, as required

Subzero cooling treatments are used if necessary

The salt used in the hardening (rectified) bath is principally barium chloride with 3 to 5% sodium and/or potassium-chloride. With the sodium (or potassium) chloride addition the operating range of this salt is 1725 to 2400 F.

The graphite rod is removed for cleaning only when the bath temperature is raised or lowered through either, or both, 1800 F and 2200 F; this amounts to four times per operating cycle.

The use of graphite-rod rectified salt baths for the hardening of tool steels is still in the developmental stage. From the results thus far achieved by the two organizations mentioned above it is evident that uniformly clean work, free from decarburization and from scale or discoloration is possible at distinct savings when compared with previous salt bath hardening techniques.

The author wishes to acknowledge, with thanks, the cooperation of the following individuals and organizations in furnishing information for this article:

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E. F. Houghton and Co., Philadelphia, Penna.

Precision Metal Parts Produced by Electroforming

by H. R. CLAUSER, *Associate Editor*, MATERIALS & METHODS

DURING THE PAST FEW YEARS electroforming has developed rapidly and has been successfully applied to a variety of metal forming jobs. These developments and actual applications have advanced this relatively new method to the point where the engineer should include it in his considerations when deciding on the best method or process to manufacture a particular metal product. Electroforming offers some distinct advantages, especially in the production of parts requiring exceptional surface smoothness and high dimensional accuracy. Because of these and other capabilities, it makes available to production men and parts designers a method which should solve many of their special processing problems.

The purpose of this article is critically to survey the electroforming process: describe briefly its development and how it works; list and discuss the materials which can be electroformed; state its characteristics, capabilities and limitations, and compare it with other metal forming methods; and finally, outline its field of use and application.

Development of the Process

Electroforming as a method of producing metal parts is actually an extension of electroplating. Plating generally involves deposits of metal up to around 0.0001-in. thick for purposes of protecting or decorating a previously formed part. Electroforming is principally concerned with the primary shaping of a part by the build-up of electrodeposited metal on a mold or matrix.

Although electroforming as a practical metal forming method is relatively new, the basic process itself is not. The use of electrotyping (electrodepositing copper on a wax mold), which might be considered a kind of electroforming, dates back over 100 years. Around 40 years ago electrodeposition was first applied to the manufacture of molds for making phonograph records. These two applications make use of copper and nickel. Building up parts by electrodeposition of iron was a laboratory method until less than ten years ago when the United States Rubber Co. first began to experiment with the method. They were in search of a new method of making rubber tire molds and began research work which finally resulted in the development of their present Ekko process for forming metal parts by electrodeposition.

Their first investigations were concentrated on finding which of the numerous variables involved were critical and required close control. They found that these were: pH factor, ferric-ion concentration, temperature, and surface tension. Their next step was to work out means of controlling these critical variables. This was done by developing the necessary instrumentation and carefully training personnel in the electroforming technique.

With this accomplished, problems of cost still had to be licked to make the process commercially feasible. World War II hastened the development work for several reasons. The Services demanded some unusual parts which could be made no other way; the facilities of other conventional forming methods were overtaxed; costs were only a secondary consideration. Thus, as a result of the accelerated development work, techniques were improved and costs cut so that now electroforming is finding a definite place among the metal forming methods. Credit for the job of developing the Ekko process of electroforming to its present status goes to Dr. E. H. Wallace and his associates at the United States Rubber Co.

> Electroforming has characteristics which suit it to production of parts with intricate detail or requiring smoothness and dimensional accuracy.

The Electroforming Technique

The electroforming process is performed essentially as follows. A die or mold is made from a master pattern of the part to be formed. This mold is termed the matrix. It is a negative impression of the finished part and serves as the base for electrodeposition of the metal. The matrix is placed in an electroplating bath where the form of the part is built-up by electrodeposition. After the metal has been deposited on the matrix to the required thickness, the matrix is re-

A computing cam being formed by electrodeposition partially completed.

moved from the bath and separated from the electrodeposited metal. The resulting electroformed part is an exact duplicate of the master pattern.

The making and use of the matrix is probably the most important step in the electroforming process. Three different techniques are possible. One of these makes use of a low temperature melting matrix with a melting point of 200 to 500 F. For this type of matrix bismuth-lead alloys are the most widely employed. The low-melting matrix can be formed from the master pattern by any one of several methods—die casting, permanent mold casting, plaster mold casting or hobbing (stamping or pressing the master into the softer matrix material). Depending upon the requirements of the electroformed part, the matrix may be buffed or polished to any desired surface finish.

Before the matrix is put into the electrolytic bath it is covered with a parting compound. After the metal has built up to the desired thickness in the bath, the matrix is separated from the electroformed part by melting it away from the part.

The low-melting matrix technique presents some problems. Because of the low melting point of the alloys used, they tend to be dimensionally unstable around room temperature, and the surface finish desired is sometimes difficult to maintain. To minimize these problems, improved low melting materials for matrices are constantly being sought. Another problem encountered—although not particularly serious—is that of traces of the matrix remaining on the part after the matrix has been melted out. It is necessary to remove these bits of matrix material by mechanical hot-brushing or by electrolytic stripping (deplating). This involves placing the part in an electrolytic bath, reversing the electroforming procedure, thus dissolving off the matrix particles.

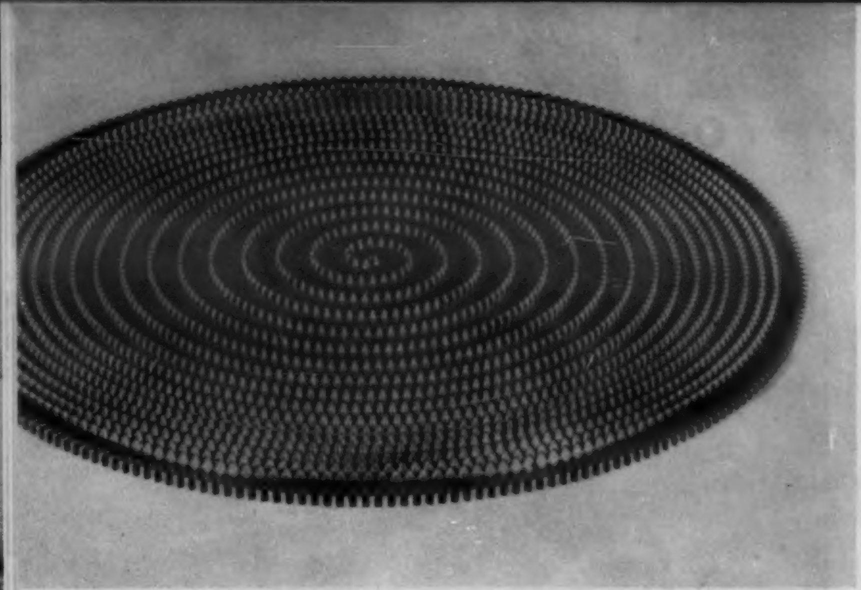
Another technique makes use of a steel mandrel as the base for the electrodeposition of the metal. The mandrel is machined or ground to the shape, dimensions, and finish desired. A parting compound is used to prevent the locking of the mandrel to the electrodeposited metal. To allow for this parting compound, the mandrel is made 0.0002 to 0.001-in. undersize. A wide variety of parting compounds can be used; they include thin films of low temperature melting metal, such as tin or cadmium, and films of wax or lacquer.

The mandrel method can be used for any part whose design permits the mandrel to be pulled away from the electroformed part. Depending upon the design of the part, one or several mandrels may be used. When more than one is used they are interlocked in such a way that each can be drawn independently from the formed part.

To separate the mandrel from the electroformed part, heat is first used to melt the parting compound film; then pressure is applied and the mandrel is forced away from the part. Because it is possible to use the same mandrels to produce a quantity of the same part, they are usually made of hardened steel.

A third method possible is the use of a soluble matrix. The technique is essentially the same as that for the low temperature melting matrix. The matrix can be made of any material that will not attach itself to the electrodeposit and which can be dissolved by an acid or an alkali. Some materials which have been used successfully are aluminum, zinc, and magnesium.

All three of the above techniques have distinctive characteristics which suit them to particular types of electroforming work. The steel mandrel and the soluble matrix methods are applicable to very close tolerance work and to applications where extremely high surface smoothness is required. Parts accurate to ± 0.0002-in. are attainable as compared to ± 0.002-in. possible with the low-temperature melting matrix method. The low melting matrix method is the cheapest of the three and is satisfactory for work to tolerances of around ± 0.002-in. The soluble matrix technique is used only in designs where steel mandrels cannot be used because of the shape and complexity of the part and where the tolerances and finish cannot



mputing cam for coastal gun batteries made by electroforming. Accuracy is required to produce cam shape and spacing.

be achieved by the low-temperature melting matrix procedure.

Materials That Can Be Electroformed

The metals which at present can be electroformed most practically are iron, copper and nickel. Chromium can also be electroformed, but is used only where high hardness and abrasion resistance is required.

To meet special surface requirements any of the regular plating metals may be plated on the electroformed part. In many applications where close tolerances cannot be maintained or where extra surface smoothness cannot be achieved by standard plating practice, a thin layer of the special surface metal is first electrodeposited on the matrix; this layer of metal then becomes the base for electroforming the body of the part with the base metal. It will be noted that this technique is just the opposite of standard plating procedure. Indeed, it would seem to those familiar with plating practice that in some cases—for example, depositing iron on chromium—such an operation could only be performed, if at all, in the laboratory. However, close control over the critical factors mentioned in the beginning of the article, make the procedure commercially practicable.

In some applications the parts have been built up by electroforming several laminations of different metals on the matrix. Up until now little advantage has been observed to this method of electroforming because of the extra operations and the care required. Generally, a satisfactory part can be produced with somewhat less effort using a single material.

Cross-section of computing cam tooth. Structure consists of (from the outside inward) 0.003 in. nickel, 0.010 in. iron, a second layer of nickel 0.003 in. thick and the remainder is iron.

Of the metals applicable to electroforming, iron is the most widely used. Because of its unique characteristics electroformed iron might justly be considered a new engineering material. The accompanying table lists some of its properties and compares it with low carbon steel. Also included is a photomicrograph showing the structure of electroformed iron.

Electroformed iron is composed of 99.8% pure iron; the remaining 0.2% is made up of traces of copper, manganese, silicon and carbon. Its crystal structure is needlelike; the needles are at 90 deg. to the electroformed surface. In the as-electroformed state the iron has a hardness of around 250 BHN and a tensile strength of 50,000 to 55,000 psi. In the fully annealed condition the hardness drops to around 140 BHN, but there is no change in the tensile strength, (approximately 50,000 psi.); the ductility increases as indicated by an increase of 10% in elongation.

A significant characteristic of electroformed iron is that it is close to absolute density. The virtual absence of porosity is evidenced by the fact that on a vacuum test that has been running for six months a sample of electroformed iron has proved to be less porous than a piece of glass submitted to the same test.

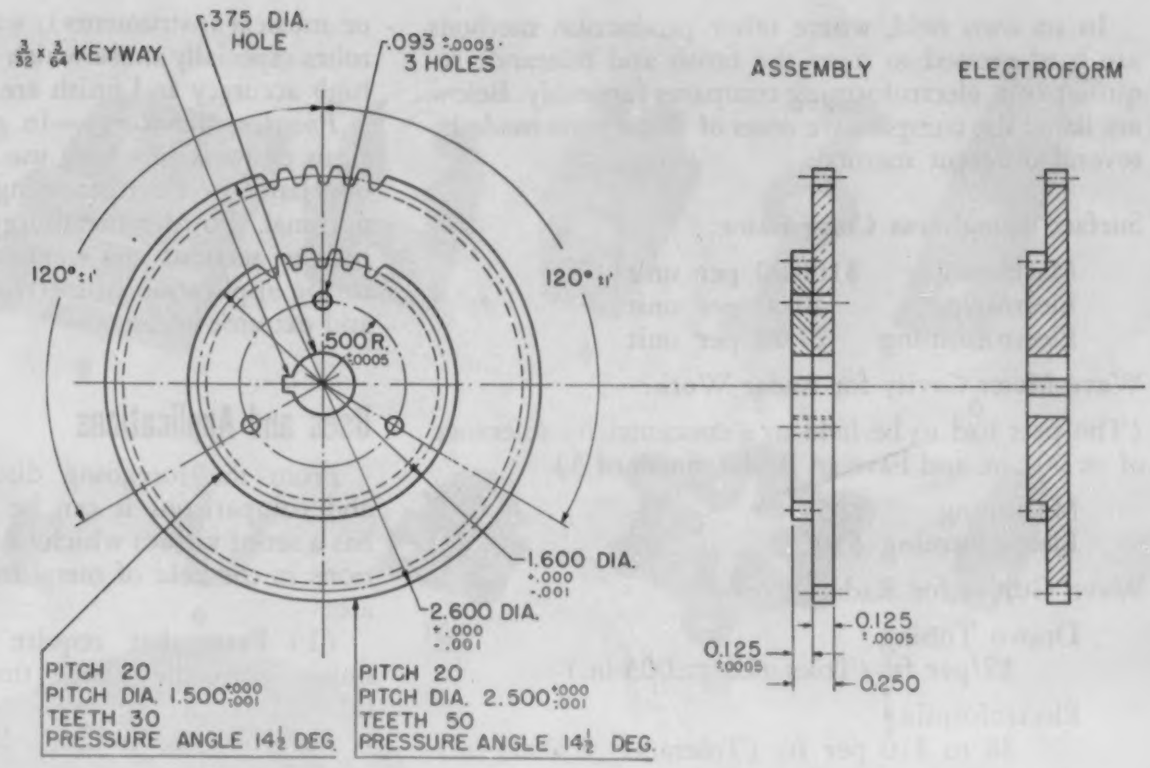
In its weldability and heat treating characteristics, electroformed iron is similar to low carbon steel. Its machinability resembles that of brass, although it is harder and tougher than cold rolled steel. The tool settings are about the same and the shavings have the stringy appearance generally associated with machining brass.

Characteristics, Advantages, Limitations

Like all production methods for metal parts, electroforming has some unique characteristics which offer certain advantages which cannot be duplicated by other processes; it also has its limitations. In surveying an engineering process, its capabilities and limitations as well as its relation to other methods must be considered.

Perhaps the two most outstanding characteristics of electroforming are the extremely high surface smoothness attainable and the very close tolerances to which it can work. There is almost no limit to the surface smoothness or the dimensional tolerances possible. These two characteristics of finish and tolerances are almost solely dependent upon the matrix quality. It has been pointed out previously that tolerances on the order of ± 0.0002-in. are possible. Surface finishes around 5 micro in. (R. M. S. value) are easily obtainable; there have been applications in which finishes with an R. M. S. value of 2 were achieved. No additional finishing operations are required to secure these extremely smooth surface finishes; the final finish is created in the electroforming operation.

Another important characteristic of the electro-



This gear has been redesigned to take advantage of the electroforming method.

forming process is its ability to produce accurately and economically parts having very intricate or minute details. An example of this is the computor cam which is illustrated in this article. Producing parts such as this, with hundreds of projections each one placed slightly different, would be a tedious and costly job by machining methods; only by electroforming can quantities of the part be produced in reasonable time.

The electroforming method can be employed in parts with sections up to ½-in. thick. There is almost no limit to the thinness of section which can be formed. Parts of electroformed foil 0.00008-in. thick have been produced successfully. In size of parts possible, there are no definite limits. The maximum dimensions possible are only limited by the size of the tanks available for the electroforming operation. As for shapes, the process is most applicable to parts with flat contour shapes and to tubular or hollow products. There are practically no restrictions as to cross sectional designs in tubular products; tapered, round, rectangular, elliptical sections, etc., can all be electroformed. There is one limitation to be observed in electroforming parts with recesses in the design. Metal cannot be effectively electrodeposited in recesses which are deeper than they are wide.

Electroforming is adaptable to mass production techniques in the same way as such methods as die casting or semi-automatic plating. Parts cannot be produced in a matter of minutes. The time required to build up parts in a bath by electrodeposition is figured in terms of days. Because of the time element, a set-up using electroforming necessarily involves a great many tanks. However, in its favor is the fact that the equipment is not very elaborate, and the cost of equipment is relatively low.

Electroforming is a high precision metal forming method and consequently production costs are relatively high. It cannot compete with other processes in the mass production of parts where the tolerances are large or moderate and where high surface smoothness is not required. There is possibly one exception to this. In *small*-quantity production it will compete with die casting. In die casting the unit cost is high for small runs because of die cost; in electroforming the unit cost is not appreciably affected by small production runs.

Physical and Mechanical Properties of Electroformed Iron as Compared to Steel

	Low Carbon Steel (App. 0.2% C., hot worked)	Electroformed Iron
Melting Point F	2,500	2,786
Annealing Point F	1110-1382	1110-1663
Coefficient Linear Expansion per deg. F	6 x 10⁶	6.6 x 10⁶
Specfic Gravity	7.83	7.87
Tensile Strength, psi. (approx.)	55,000-65,000	50,000
Modulus of Elasticity, psi.	30 x 10⁶	29.7 x 10⁶
Elongation % in 2 in.	30-40	40
Brinell Hardness (annealed)	120-140	155-165

In its own field, where other production methods are hard-pressed to meet the finish and tolerance requirements, electroforming compares favorably. Below are listed the comparative costs of three parts made by several different methods.

Surface Roughness Comparator:

Machining	\$100.00 per unit
Electrotype	40.00 per unit
Electroforming	27.00 per unit

Wave Meter Cavity for Radar Work:

(The part had to be held to a concentricity tolerance of ±.001 in. and have an R.M.S. finish of 5)

Machining	\$85
Electroforming	\$50

Wave Guides for Radar Work:

Drawn Tubing
\$2 per ft. (Tolerance ±.003-in.)

Electroforming
\$8 to \$10 per ft. (Tolerance ±.0003-in.)

The last listed item illustrates clearly the tie-up between costs and product requirements. In this case, wave guides produced by conventional methods, did not give the accuracy required. Using electroforming, the cost was higher but the requirements could be met.

Now having considered the various characteristics of electroforming, let us see how this process specifically compares with some of the other production methods for metal parts.

Machining—In general, electroforming supplements and extends machining practice. An example of this is the use of electrodeposition for resizing. Heavy deposits may be adhered to mismachined or worn parts to bring them back to correct size. Electroforming also makes possible the fabrication of designs with internal shapes and contours which cannot be made practicably by machining methods. Machining and grinding are often used as an aid to the electroforming process for the forming of mandrels.

Casting—Electroforming has sometimes been referred to as a "cold casting" process, because it is unnecessary to allow for shrinkage in the pattern work. Besides the absence of shrinkage, the oxidized rough surfaces associated with casting at elevated temperatures are eliminated in elctroforming. In addition, when compared with products prepared by low temperature casting, the dimensional stability of electroformed parts after forming is superior. Casting methods have the advantage of a great variety of metal compositions. Production electroforming, in comparison, has only three main metals—iron, copper, nickel—to work with and no alloys. Electroforming can seldom be used for designs with sections thicker than ½-in, or with reinforcing ribs, bosses and lugs.

Cold and hot forming methods—Electroforming cannot attempt to mass produce all the great variety of parts possible by the various forming processes. However, it must definitely be considered on such parts as reflectors, propeller blades, dial horns (radar or musical instruments), where internal surface contours especially those which are compound, and where high accuracy and finish are required.

Powder Metallurgy—In general, there are few designs or parts in which use of powder metallurgy on one hand or electroforming on the other would be optional. Powder metallurgy is usually employed for heavier sections and moderate accuracy as compared to the application of electroforming for thin sections and extreme accuracy.

Uses and Applications

From the foregoing discussion of characteristics and comparisons it can be seen that electroforming has a set of virtues which fit it best for certain applications in the field of metal forming. Specifically, these are:

(1) Parts that require an extra high surface finish, especially where that finish is required on internal surface contours such as tubing, flow and venturi nozzles, complex bends and elbows, radar antenna and horns.

(2) High precision parts in which tolerances on the order of ±0.002-in. and less must be met. Also products that require absolute accuracy of shape or form. For example, wave meter cavities for radar work in which adjacent interior faces must be absolutely normal to each other.

(3) Parts having intricate details which cannot be made by any other method or which would otherwise require hand or extended machining methods. Some products that fit into this category are computing cams for calculating machines, surface roughness comparators, heat exchangers.

(4) Parts where the quantities required are too small economically to use die casting.

(5) Resizing and coating applications such as electrodepositing metal on plastics to enhance the plastic's properties and building up of worn machine parts.

In designing a part to be produced by electroforming, the designer should take advantage of the method's special characteristics. In this way a better product can be made at a lower cost. An example of how electroforming can be effectively used is shown in the redesign of a brass gear assembly. (See drawing). This gear assembly has rather high limits of accuracy. Conventional construction would be to cut the two gears separately and assemble with pins. Because of the tolerances this is a difficult and costly operation. To produce this part by electroforming the assembly should be redesigned so that the two gears are formed in one operation. In this way angular rotation and dimensional tolerances would be assured. In addition, substitution of iron for brass would give a better weaving gear.

Thus the engineer has available a relatively new metal forming method. We have seen that it has some special and unique characteristics which can be used to advantage. In its particular field of use there is no doubt that its application will expand and in the future many more of its possibilities will be explored.

MATERIALS & METHODS MANUAL

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This is another in a series of Manuals on engineering materials and processing methods, published at periodic intervals as special sections in Materials & Methods. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal forms or with essential principles, best procedures and operating data for performing specific metalworking processes.

Tool Steels — Types and Treatment

by Robert S. Burpo, Jr.,

Associate Editor, MATERIALS & METHODS

The useful qualities latent in all tool steels will be unavailable unless the steels are properly treated. Thus, is important to anyone handling tool steels to give caref consideration to time and temperatures and to know what happens to the steel at various points in the heating and cooling cycle. This manual emphasizes these factors a also presents information on the various types, compositio and uses of tool steels available today.

Contents

Materials & Methods, July 1946

(Published since 1929 as Metals and Alloys)

...ble 1 — Classification and Characteristics of Representative Tool Steels[1]

Type	Ref. No.	General Characteristics	C	Mn	Si	Cr	W	Mo[6]	Other	Forging[3]	Annealing[4]	Normalizing[5]	Hardening	Critical, Ac[1]	Hardening and Tempering Information See,
Plain Carbon Tool Steels	1	Water hardening steels, they are listed in order of increasing depth of hardness (for details of hardness penetration see Table 6), these steels harden with a very hard (Rc 66-68) case and a tough (partially hardened) core	0.95	0.25	0.20	—	—	—	0.20	1900-1450	1450	1650	1450-1500, water quench	1350	Tables 6 and 8, Figs. 2a, 2b, 3 and 4
	2		0.95	0.25	0.20	—	—	—	—	1900-1475	1450	1500	1500-1550, water quench	1350	
	3		1.05	0.35	0.20	—	—	—	—	1900-1475	1450	1600	1425-1500, water quench	1350	
	4		1.10	0.30	0.50	0.25	—	—	—	1900-1475	1450	1600	1425-1500, water quench	1350	
	5		1.25	0.30	0.25	—	—	—	—	1650	1350-1400 (See Table 7 for additional annealing information)	—	1410-1430, water quench	1330	
Medium Alloy Tool Steels	6	Deeper hardening, water quenching steel	0.55	0.50	0.80	—	—	0.45	—	2000	1350-1375	—	1550, water quench (for small tools, 1550-1575, O. Q.)	—	Table 9
	7	Semi-high speed, wear resistant, and very hard water quenching steel	1.30	—	—	0.75	3.75	—	—	1800-1400	1470-1500 See Table 10	Not normalized[7]	1500-1550, water quench	—	Table 10 and Fig. 5
	8	Tough at high hardness, either oil or water hardening	0.60	0.75	1.90	0.25	—	0.30	—	2000-1550	1475, See Table 11	Not normalized[7]	1550-1600, water quench (if oil quenched, heat to 1600-1650)	1400	Table 11 and Fig. 6
	9		0.45	0.70	—	1.00	—	—	V 0.20	2000-1650	1450, See Table 12	Not normalized[7]	1625-1675, oil quench (if water quenched, heat to 1500-1525)	1360	Table 12
	10		0.52	0.90	2.00	—	—	1.00	—	1800-1500	1440, See Table 13	Not normalized[7]	1650-1675, oil quench (if water quenched, heat to 1600)	—	Table 13
	11	Most of these are oil quenching (some may be water or air quenched) deep hardening steels	0.90	1.25	0.25	0.50	0.50	—	—	1900-1550	1450	1600-1650	Preheat 1200-1250, oil quench from 1450-1500	1370	Table 14a
	12		0.90	1.60	0.25	—	—	—	—	1950	1375-1400	1500	1420-1475, oil quench	—	Table 14
	13		0.92	0.30	0.35	3.80	—	0.55	V 0.55	2000-1600	1500-1600	Not normalized[7]	Preheat 1400, air or oil quench from 1700-1800	—	
	14		1.10	—	—	0.60	1.75	—	V 0.25	1800-1650	1450	1600	1570-1650, oil quench	—	
	15		0.50	—	—	1.25	2.75	—	V 0.20	1900-1650	1475	Not normalized[7]	Preheat 1200-1300, oil quench from 1700-1800	1425	
	16		0.43	0.25	0.30	1.35	1.95	—	—	2000-1600	1500-1600	Not normalized[7]	Preheat 1400, oil quench from 1700-1800	—	
	17	These steels have greater red-hardness and resistance to the effects of heat than those in the above groups	0.30	—	1.00	5.00	1.25	1.36	—	2000-1700	1625-1650	Not normalized[7]	Preheat 1400-1500, air cool from 1850-1900	1535	Table 15 and 15a
	18		0.40	—	1.05	5.00	—	1.35	V 0.35	2000-1650	1625	Not normalized[7]	Preheat 1400-1500, air cool from 1800-1850	1505	
	19		0.55	0.30	0.40	4.00	—	0.50	V 1.00	2000-1700	1550	Not normalized[7]	Preheat 1200, air cool from 1650	1475	
	20		1.0	0.50	0.45	5.0	—	1.25	V 0.30	—	—	—	Air cool from 1750-1850	1418	
	21		1.00	2.00	0.30	2.00	—	1.00	—	—	1550	—	Air cool from 1600	—	
High Alloy Tool and Die Steels	22	The steels of this group are mostly hot-work steels, oil and/or air hardening, highly resistant to wear, abrasion and the effects of heat	0.28	—	—	3.25	9.00	—	V 0.25	2050-1700	1650	Not normalized[7]	Preheat 1500-1550, air cool from 2000-2250	1520	Tables 16 and 16a, Fig. 7
	23		0.37	0.30	0.30	3.00	13.50	—	V 0.30	2000-1600	1575-1600	Not normalized[7]	Preheat 1500-1550, air or oil quench from 2000-2200	—	Table 17
	24		0.45	0.60	1.50	7.50	7.50	—	—	—	—	—	—	—	
	25		1.00	0.40	—	5.25	1.15	—	V 0.40	2000-1650[8]	1650	Not normalized[7]	Preheat 1450-1500, air cool from 1775-1825	1460	Table 18 and Fig. 8
	26		1.50	—	—	11.50	—	0.80	V 0.20	2000-1650[8]	1650, See Table 26	Not normalized[7]	Preheat 1450-1500, air cool from 1800-1850	1490	Table 19
	27		2.25	0.25	0.45	11.50	—	0.80	V 0.20	2000-1650[8]	1650	Not normalized[7]	Preheat 1450-1500, air cool from 1800-1850 (oil hardening)	1440	Table 20
	28		2.25	0.30	1.00	11.00	1.00	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	29		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

...se are representative tool steels illustrating a type; there are many more analyses on ... market, but they represent minor variations from these examples
... compositions are typical (and in some cases averages) of particular steels; the per... ages of elements are liable to vary within manufacturing tolerances
... first temperature is the highest temperature to which it is recommended that the steel ... heated preparatory to forging; the second is the minimum temperature at which any ... ing should be done

4 The temperature given is that to which the steel should be heated if it is to be an... by slow cooling; see individual references for data on "cycle annealing"
5 Temperatures to which the steel is to be heated prior to air cooling
6 All temperatures listed are steel temperatures—not necessarily the temperatures in furnaces
7 In general those steels that are not normalized must be annealed after forging
8 After forging, equalize at 1450-1550 and slow cool

High Speed Steels	30	18-4-1 standard high speed steel	0.73	0.28	0.28	4.00	18.00	—	V 1.00	2000-1700	1650	See Table 26 for additional annealing information	Not normalized[7]	Preheat 1500-1600, austenitize at 2300-2400	1545	Figs. 9 and 10
	31	18-4-2	0.82	0.25	0.35	4.25	18.50	0.70	V 2.10	2000-1700	1650		Not normalized[7]	Preheat 1500-1600, austenitize at 2325-2375	1560	Figs. 9 and 10, Tables 22 and 22a
	32	14-4-2	0.80	0.30	0.30	4.00	14.00	—	V 2.00	2000-1700	1600-1650		Not normalized[7]	Preheat 1450-1600, austenitize at 2200-2300	—	
	33	18-4-1 plus 5% cobalt	0.75	—	—	4.00	18.00	0.75	Co 5.00 V 1.15	2000-1700	1650		Not normalized[7]	Preheat 1500-1550, austenitize at 2375	1525	
	34	14-4-2 plus 5% cobalt	0.80	—	—	4.00	14.00	0.75	Co 5.00 V 2.00	2000-1700	1650		Not normalized[7]	Preheat 1500-1550, austenitize at 2350	1515	
	35	20-4-1 plus 12% cobalt	0.80	0.20	0.30	4.25	20.50	0.60	Co 12.25 V 1.30	2100-1800	1600-1650		Not normalized[7]	Preheat 1500-1650, austenitize at 2325-2375	—	
	36	Mo-Max type	0.74[10]	—	—	3.75	1.55	8.75	V 1.10	2050	1550		Not normalized[7]	Preheat 1200-1500, austenitize at 2150-2250	—	
	37	Type M-1 molybdenum high speed steel	0.83	—	—	4.0	—	8.0	V 2.0	2000-1600	1450-1550		Not normalized[7]	Preheat 1250-1500, austenitize at 2150-2250	—	
	38	Type M-2 molybdenum high speed steel	0.80	—	—	4.0	1.5	8.5	V 1.0	2000-1600	1450-1550		Not normalized[7]	Preheat 1250-1500, austenitize at 2150-2250	—	
	39	Chromium - tungsten - molybdenum	0.83	—	—	4.15	6.40	5.00	V 1.90	1950-1700	1600		Not normalized[7]	Preheat 1400-1500, austenitize at 2200-2300	1530	
Miscellaneous Tool and Die Steels	40	Low carbon steel[12] for plastics or die casting dies	0.05	0.18	—	—	—	—	—	Hobbed[11]	—		—	Carburize	—	
	41	Easily machined steel for die casting and plastics dies	0.30	0.75	0.50	0.80	—	0.25	—	2000-1650	1500		Not normalized[7]	Carburize, or quench from 1550-1575	1350	
	42	Nos. 42 thru 46 are "Graphitic" steels — they contain free carbon (graphite) which produces a tool and die steel that is wear- and scoring-resistant, easily machined and heat treatable	1.50	0.50	0.80	—	—	0.25	—	1950-1500	See Table 25 for additional annealing information		1600	1450-1550, oil quench	—	Table 24
	43		1.50	0.50	0.65	—	2.80	0.50	—	1900-1500			1700	1450-1500, water quench	—	
	44		1.50	0.30	0.20	—	—	—	Al 0.16	1925-1500			1700	1450-1500, brine quench	—	
	45		1.50	1.25	1.00	0.50	—	0.50	Ni 1.75	1950-1500			1700	See Table 24	—	
	46		1.50	0.50	0.90	—	—	—	—	1925-1500			1600	1450-1550, brine or water quench	—	

[9] *After forging, equalize at 1450-1500 and slow cool*
[10] *This steel is made in several carbon ranges as follows: 0.65 - 0.70, for tools requiring high toughness; 0.71 - 0.77, a compromise between toughness and hardness; 0.78 - 0.84, for tools having high hardness*
[11] *This steel is hobbed, or shaped by die sinking*
[12] *This may be called a die iron; sometimes 0.50% Cr and 1.2% Ni are added to increase the strength and toughness of this steel*

Introduction

Tool steels are a vital material in our industrial economy. They are so numerous, have so many different treatments and applications, and pose such varied and interesting metallurgical questions that it would be impossible to treat this entire topic adequately in the space usually alloted to a Materials & Methods Manual. This Manual, then, is limited to a brief survey of the types of tool steels in common use, a condensed study of the practical aspects of the metallurgy of this special type of steel, and a summary of the most up-to-date heat treatment information.

Until the early twentieth century, carbon tool steels were the only tool materials available. Then came the development of the first high speed steel by Taylor and White in 1900. This was another question of which came first the hen or the egg—forgings were appearing on the market, forged alloy steel armor was being specified for warships, and suitable cutting materials were needed for the machining of these products. These cutting steels were developed to machine the forgings, and forging progress was accelerated because cutting tools were available to machine them. All this lent impetus to the expansion in the use of alloy ordnance and engineering steels. Steel production methods and process were being improved also during this era. Thus the new tool materials were expanded so greatly that today there are literally thousands of compositions of tool and die steels on the market.

What is Tool Steel?

Tool steels are the steels used for tools (such as lathe tools, drills, taps, reamers, punches, dies, etc.) and they can be divided into four categories as follows:

(1) Carbon tool steels
(2) Medium alloy tool steels
(3) High alloy tool steels
(4) Miscellaneous tool steels

Carbon tool steels are the oldest type. The newer developments, the alloy tool steels, fill needs that could not be met by the carbon type of tool materials; they are deeper hardening, stronger, more resistant to abrasive wear and erosion, resistant to softening at temperatures in the neighborhood of 1000 F, and they are more expensive. The fourth class, the miscellaneous group, includes the graphitic tool steels and some low carbon (carburizing grade) die steels. Typical compositions of steels in each of these categories are listed in Table 1.

How Tool Steels are Made

A better understanding of the nature and treatment of tool steels is obtained if a brief study of the manufacturing process is made. Today, all material that bears the label *"Tool Steel Quality"* is a precision-made product.

Uniform quality at reasonable cost in tool steel is possible through the use of the electric furnace. By far the greatest proportion of modern tool steels is made in basic electric furnaces; these range in

size from 3 to 125 tons. Because analyses can be controlled in the electric furnace far more accurately than in any other type, our tool steels are the highest quality steels available.

The major steps in the manufacture of quality steels for tools are indicated in the accompanying flow sheet (Fig. 1). As can be seen from this flow sheet, the "raw" steel goes through a number of hot and cold working operations each one of which may adversely effect the quality of the product if not carefully controlled. Just as with other steels, the amount of mechanical working and the temperatures at which this working takes place can change the grain size and consequently, many of the physical properties.

Commercial Forms

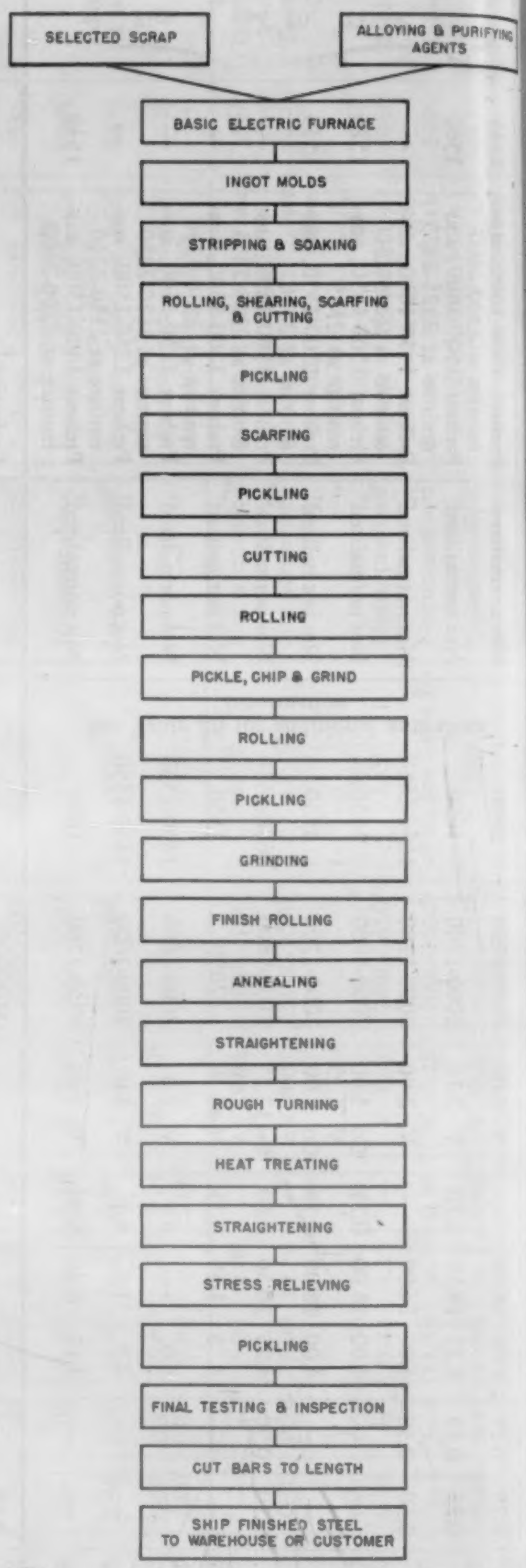
The standard forms in which tool steels are marketed can be grouped under three headings: (1) rolled billets and bars of various shapes (some of these may be cold finish) (2) forgings (bars, disks, die blocks, etc.), and (3) cast shapes. The wrought forms are all produced by rolling or forging ingots into blooms and then to billets and other raw forms. The sizes and shapes of these raw forms are listed in Table 2.

Most of the tool steel is sold in the form of rolled or forged bars, and a minor portion goes into disks, blocks and special shapes. Some of the common standard forms and the range of sizes in which they generally are available are tabulated in Table 3. Not all tool steels are sold in the sizes and forms listed in Table 3, but these are generally available in the high production items. The manufacturers usually finish the tool steels to size tolerances that have been standardized; these size tolerances are obtainable from the mill (in the manufacturer's stock list).

It is customary to sell these products in the annealed condition; this insures a relatively stress-free and machinable material. For certain applications, and for special types of steels, other heat treatments may be specified. Gradations in surface finish are sometimes available: such as "rough turned" and "smooth turned" finish. These physical differences that must be specified when tool steels are ordered are summarized in Table 4.

Table 2

Form	Width, Inches	Thickness, Inches	Cross Section, Square Inches
Bloom	Width equals thickness		36 (min.)
Billet	1½ (min.)	1½ (min.)	2¼ to 36
Slab	10 (min.)	1½ (min.)	15 (min.)
Sheet Bar	8 to 16	½ to 2	4 to 32



NOTE:
The various points at which inspections and testing take place have been omitted.

Fig. 1—The quality of tool steel is due largely to the care in manufacture. Here are the principal steps in the production of any tool steel.

The Alloying Elements in Tool Steels

Tool steels are in general, fairly complex alloys, and, with the exception of plain carbon tool steel, they depend upon the combined effects of several alloying elements for their special properties. As a means of better understanding the types of tool steels and their characteristics the following remarks concerning the effects of each alloying element found in commercial tool steels are included.

Carbon. Carbon is the most important single element in tool steel. Variations in the percentage of carbon present in the steel produce greater changes in physical properties than is possible with any other element. The degree of hardness imparted to a steel by quenching from a suitable temperature is a function of the carbon content only. (The depth of hardening, i.e., the hardenability, is determined by the alloy content).

Carbon combines with iron in the steel to form iron carbide (FeC); carbon also forms carbides with chromium, tungsten and vanadium. The presence of the hard carbide particles in the steel increases its strength and wear resistance and decreases its ductility. Therefore high carbon (plain carbon) tool steels will be very hard, wear resistant, shallow hardening and brittle after being quenched. Plain carbon steels are water hardening tool steels.

If other elements are included in the steel, the embrittling effects of high carbon can be reduced.

Chromium. This element combines with carbon to form very hard carbides. Up to 1.8% the addition of chromium to steel increases its hardenability markedly; beyond this amount, the extent to which the chromium carbides go into solution alters the effect of the element; this means that for maximum hardenability, all the carbides should be in solution.

Small amounts of chromium toughen the steel (giving it greater impact strength) and increase its strength; the machinability decreases as the chromium increases. Unless the chromium is balanced with some other alloy (such as nickel), the hardening range of the steel is narrowed.

Air hardening qualities (caused by changes in the transformation characteristics) are imparted to the steels by 5 to 15% chromium. Likewise, a certain degree of red hardness and considerable resistance to wear and abrasion results from the presence of chromium in the steel.

Cobalt. Cobalt is rarely used except in certain high speed steels. It is used in amounts of 5 to 8% to increase the red hardness of the steels; some hot work steels subject to high temperatures contain small amounts of it. Cobalt raises the transformation point and causes the iron carbides to become unstable, permitting graphitization to occur unless the steel is heat treated with care. Cobalt steels are subject to some decarburizing tendencies during heat treatment.

Manganese. This element is present in all

Table 3—Summary of Common Wrought Forms and Sizes (in In.) of Tool Steels

Form	Rolled		Forged		Centerless Ground		Polished		Cold Drawn	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Bars, Round	$\frac{1}{4}$	4	4	$7\frac{1}{8}$	0.020	$3\frac{1}{2}$	0.045	$2\frac{1}{2}$	0.013	$2\frac{1}{2}$
Square	$\frac{1}{4}$	$1\frac{3}{4}$	1 and up		—	—	—	—	—	—
Flat	$\frac{1}{4}$x$\frac{1}{8}$	4x3	To limit of ingot size		—	—	—	—	7/32x1/16	$4\frac{1}{2}$x1
Octagon	$\frac{1}{4}$	$2\frac{1}{4}$	$\frac{3}{4}$ and up		—	—	—	—	$\frac{1}{8}$	2
Hexagon	$\frac{1}{4}$	$2\frac{1}{4}$	$\frac{3}{4}$ and up		—	—	—	—	Up to	$2\frac{1}{2}$
Quarter Octagon	$\frac{3}{8}$	1	To limit of ingot size		—	—	—	—	—	—
Billets, Square, With Round Corners. Rounds, See Bars, Round.	Up to 4 square x 600 lb.		Up to 10 square x 2400 lb.[1]		—	—	—	—	—	—
Forgings, Discs	—	—	4 dia. x 1xtk	24 dia.x5tk	—	—	—	—	—	—
Die Blocks	—	—	4x5x4	12x12x12	—	—	—	—	—	—
Rings	—	—	4 O.D.x$1\frac{1}{2}$ I.D. x 1xtk	24 O.D.x20 I.D. x 4xtk	—	—	—	—	—	—
Flat Rolled Sheets	6x0.125 12x0.1875	12x1.250 18x1.250	—	—	—	—	—	—	—	—

[1] *Square or round cornered*

steels. In small amounts (up to ½%) its action is as a deoxidizer and desulfurizer. In large quantities it has a strong effect on hardenability. Because of the danger of quench cracking, water hardening steels are low in manganese. In the case of steels quenched in oil, manganese lowers the critical point and makes the steel non-deforming and deep hardening. Steels having over 15% manganese have air hardening tendencies (depending upon the total alloy content). It is necessary to have other alloying agents present with intermediate amounts of manganese to counteract the latter's tendency towards making the steel brittle.

Molybdenum. Red hardness, strength and ductility are increased at high temperatures by molybdenum. It is one of the most important alloys for making steels deep hardening; the addition of ¾ of 1% molybdenum to an oil hardening high carbon, high chromium steel makes it air hardening.

Molybdenum is always used in conjunction with other alloying elements; it acts as an intensifier in addition to contributing its own effects of deep hardening and improvement in elevated temperature properties.

Nickel. Nickel is used in very few tool steels (mostly in check resisting and special hot work steel) and only in small amounts; it enhances the ductility or shock resisting ability of the material.

Silicon. Like manganese, silicon is present in all steels. When used as a deoxidizer only, it is present in amounts of about ¼ of 1%. Silicon is added to shock resisting and hot work steels to improve their impact characteristics and depth of hardening. Also, it has a graphitizing influence and when present in quantities greater than ½ of 1%, carbide stabilizing elements such as molybdenum and chromium are usually included in the steel to prevent graphitization.

Tungsten. Like molybdenum, tungsten is a potent carbide former. The high red hardness of tungsten steels is one of their most important features. Tungsten also makes for fine grained, high strength steels that hold good cutting edges. In heat resisting tool steels the tungsten content is usually from 5 to 12%; in tungsten-molybdenum high speed steels, 4 to 9%; and in straight tungsten high speed steels 14 to 20%.

Vanadium. Vanadium forms stable carbides and has considerable effect on the hardenability of steels. Undissolved vana-

Table 4—Information Needed When Ordering Tool Steel

Item	Information desired
Type	Give brand name (and grade, if any)
Specification	If the steel is being purchased to a commercial or government specification, give its latest revision or form. If the material is purchased to a non-standard (customer's material or purchase) specification, all the details should be included, including basis of rejection
Size	Specify size and shape and permissible variations (tolerances)
Quantity	State quantity in pounds
Length	Indicate whether lengths are to be approximate or exact and whether multiples of the given length will be acceptable
Finish	State the desired finish (i.e., hot rolled, forged, cold drawn, centerless ground, rough or finish turned).
Condition	Indicate whether annealed, natural, or a particular heat treatment is desired.
Packaging and Shipping Instructions	Include any special packaging desired and give method of shipment (freight, air-express, ship, truck, express, parcel post) and routing; state needed delivery date.

Table 5—Characteristics and Uses of Carbon Tool Steels

Carbon Range, %	Characteristics	Applications
0.060 to 0.070	Shock resistant, tough	Brake and drop hammer dies, machinery parts, track tools, hammers, rock drills, short run hot work dies
0.070 to 0.090	Strong, moderate toughness	Tube expanders, bolt and rivet dies, pneumatic tools, swaging dies, shear blades
0.090 to 1.10	Moderate strength, wear resistant, holds good edge	Knife blades, lathe centers, hacksaw blades, dies for cold heading, cold punching, cold stamping, drawing, forming, trimming, jewelry work, minting, rivet sets, and threading dies
1.10 to 1.40	Very wear resistant, holds a keen cutting edge	Wood working tools, razors, engraving tools, file and glass cutters, paper machine knives, wire drawing dies, turning tools for brass and soft metals

dium carbides inhibit grain growth and tend to make a steel shallow hardening. If the carbides can be dissolved in the austenite during heat treatment, the steel will be deep hardening. Vanadium is also used as a deoxidizer. In plain carbon tool steels, vanadium is added to make them fine grained and tough. In high speed steels and hot working steels, vanadium aids in making the steels resistant to grain growth and to help in maintaining their hardness at elevated temperatures.

Types of Tool Steels

Referring to Table 1, we see that the common tool steels can be divided into four general types; viz. carbon, medium alloy, high alloy, and miscellaneous tool steels. For the purposes of analysis, the steels in each of these divisions will be discussed separately; their particular properties, their working and treatment and field of applications will be considered.

Carbon Tool Steels

This is the oldest type of cutting steel and had its origin in the swords and other weapons of the early steel masters and armorers. Today, carbon tool steels have wide industrial applications. Their two outstanding characteristics are their ability to be water quenched to a high ("glass hard") hardness, and their shallow hardening qualities.

Carbon tool steels depend solely upon the carbon content for their hardenability and hardness; the metallurgy of this type of steel will be considered briefly. The range of carbon in carbon tool steels is 0.60 to 1.40%; probably the most popular steels are those having a carbon content of about 1%. These steels are hypereutectoid and, therefore, in the annealed state are composed of pearlite and cementite. When they are hardened, these materials may be 100% martensitic (in the hardened portion and a relatively high temperature transformation product, usually fine pearlite, in the core).

It has been stated above that the carbon content is the major factor in determining the physical properties of carbon steels. Table 5 lists the properties and uses of steels within the range 0.60-1.40% carbon.

These carbon tool steels are all shallow hardening. From Table 6 we can see that sections over ½-in. round will not harden through. Instead, the core toughens considerably in the quench and forms a resilient backing for the hard and more brittle case. This double feature of a hard, wear resistant case backed by a tough core that absorbs much of the shock makes these materials suitable for cold heading, minting or cold striking dies where ability to stand up under shock is needed.

This shallow hardening property has its disadvantages too. On designs having thin and thick sections, the thin sections will harden through and have no tough core to strengthen them as will the heavier section. Also, the distortion during hardening is greatest in this type of steel.

Carbon tool steels make excellent edge tools (knives, razors, shears, etc.) for they hold a keen cutting edge, especially the higher carbon types (see Table 5).

The remaining elements in carbon tool steels are manganese, silicon, sulfur and phosphorus; the last two are generally considered as impurities and kept as small as possible; the other two perform definite deoxidizing and desulfurizing missions and are not considered alloying elements.

Heat Treatment and Hot Working

As is the case with any tool steel, the physical properties of finished tools and dies are to a great extent dependent upon the manner in which the forging operations have been performed. Both the intensity of working and temperature of the steel should be controlled during hot working. These steels are generally heated to 1800 to 1900 F preparatory to forging and the forging operation should be completed at a minimum temperature of 1475 F to insure a suitable (not coarsened) grain structure. If the forging is a complicated one, both normalizing and annealing should follow (prior to hardening); less complicated forged work-pieces need only be annealed before hardening. Annealing and normalizing will be discussed below.

T-T-T Curves

Among the most meaningful heat treating aids, from the standpoint of the practical man, are the triple T curves (or Transformation-Temperature-Time curves, also called S-curves).

The significance of the T-T-T curves is best illustrated by referring to Fig. 2 which is the curve (sometimes called an isothermal transformation diagram) for a 1% carbon tool steel. Time is measured on a logarithmic scale along the base of the diagram while the temperature of the steel is represented by the vertical scale. The dashed horizontal line in the upper part of the figure, labeled Ae^1, represents the lower limit of stable austenite (i.e., the critical temperature) or the lowest temperature (in this case 1360 F) to which the steel can be heated to form stable austenite.

The shaded "C"-shaped area in Fig. 2 represents the transformation zone. The line bounding this zone on the left indicates the time at which austenite starts to transform and the corresponding line on the right shows the time at which the austenite would be completely transformed at any given temperature, after cooling from some temperature above the critical. For example: If a piece of plain carbon tool steel were cooled from the austenitizing temperature to 1300 F and were held at that temperature, after 30 sec. had elapsed (see point AO), the austenite would begin to transform to a form of pearlite. When 2½ min. had elapsed the austenite will be completely transformed and the steel

Table 6—Hardening Characteristics of Carbon Tool Steels*

Steel Ref. No.	Characteristic	Diameter of Test Piece, in Inches ½	1	1½	2	2½	3
1	Depth of hardness	Hardens through	7/64	6/64	5/64	5/64	5/64
	Hardness, case, Rc	67.5	67.5	67.5	67.5	67.5	67.5
	Hardness, core, Rc	67.5	42.5	41.5	41.0	40.0	40.0
2	Depth of hardness	Hardens through	8/64	7/64	6/64	6/64	6/64
	Hardness, case, Rc	68.0	68.0	68.0	67.5	67.5	67.5
	Hardness, core, Rc	68.0	43.0	42.0	41.0	41.0	39.0
3	Depth of hardness	Hardens through	10.64	9/64	8/64	7/64	7/64
	Hardness, case, Rc	68.0	68.0	68.0	68.0	67.5	67.5
	Hardness, core, Rc	68.0	45.0	44.0	41.0	40.5	39.0
4	Depth of hardness	Hardens through	14/64	13/64	11/64	10/64	10/64
	Hardness, case, Rc	68.0	68.0	68.0	67.5	67.5	67.5
	Hardness, core, Rc	68.0	44.0	42.0	40.0	40.0	39.5

* *Water quenched from 1450 F*

will have a hardness of Rockwell 18 C when cooled to room temperature. Likewise, if a tool were cooled to 800 F, after 4 sec. (see point B) the transformation would start and it would be completed after 37 or 38 sec.; the resulting hardness of the transformation product would be Rockwell 44 C. These isothermal transformations will be discussed in more detail below.

The shaded transformation zone leads downward into a darker area on the T-T-T diagram through which several horizontal lines run. The upper of these lines marks the temperature at which austenite begins to transform to martensite (this is the Ms temperature), on being quenched from a temperature above the critical. If the steel is cooled still further below the Ms temperature, the transformation to martensite continues and the next lower horizontal line indicates the temperature at which this austenite-to-martensite transformation is 50% complete; similarly, the horizontal lines marked 80 and 90% show the temperature to which this particular type of steel must be quenched to form 80 or 90% martensite, respectively. Approximately 100% martensite is formed by quenching the steel to room temperature. The use of T-T-T curves in relation to heat treatments will be discussed below.

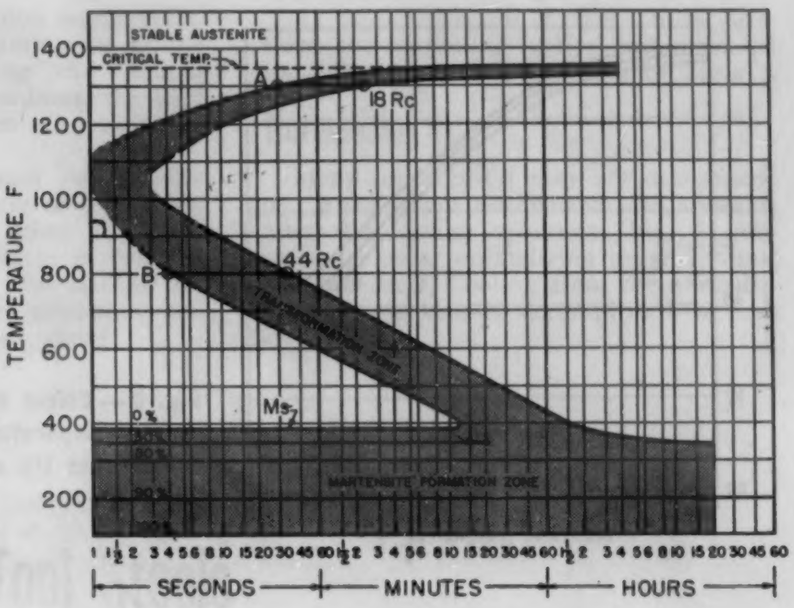


Fig. 2a — T-T-T curve showing the transformation characteristics of a 1% carbon tool steel cooled from 1450 F.

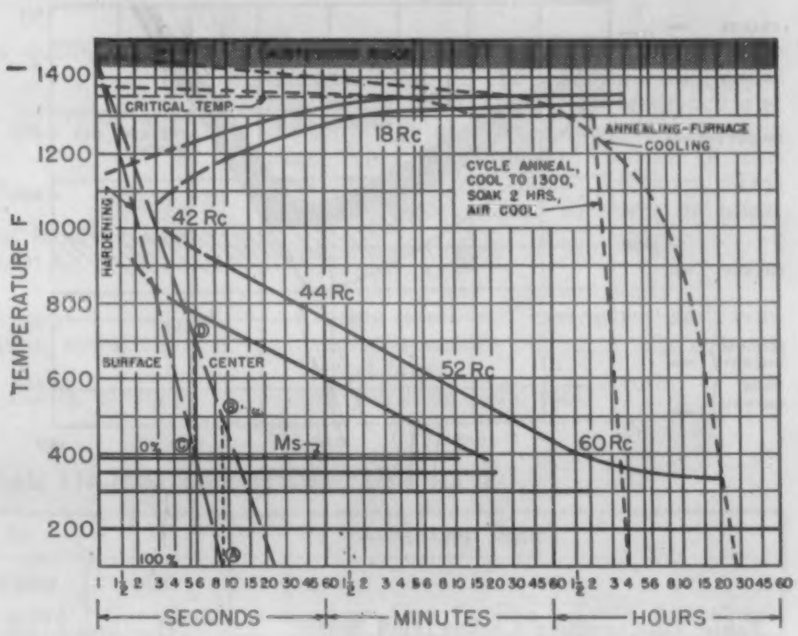


Fig. 2b — The T-T-T curve for a 1% carbon tool steel showing the various heating processes applied to this type steel.

Hardening

As noted previously, carbon tool steels are shallow hardening and must be quenched in water or brine. This means that these steels will warp and crack during quenching unless the tool is of a sensible design and is handled carefully. It is not the purpose of the Manual to list the precautions and techniques necessary to the successful hardening of carbon tool steels. Instead, the practical use of T-T-T curves as a guide to the hardener will be discussed.

Fig. 2b is the same T-T-T curve as is presented in Fig. 2a. The effects of different hardening procedures will be discussed with the aid of this curve using a 1.00 to 1.10% carbon tool steel as an example.

If a ¼-in. drill, made of 1.00-1.10% carbon steel, is heated slowly to the proper austenitizing temperature, 1450 F, held at that temperature until heated through, it can be water (or brine) quenched and hardened with little or no trouble. If the part to be hardened were a die having considerable variation in section, warpage or even cracking might be encountered when it were quenched. A glance at Fig. 2d will explain the reason. Superimposed upon the T-T-T curve are the generalized cooling curves for the surface and center of a theoretical work-piece when it is quenched in water. When the surface of the tool is at the temperature of the water and the transformation to martensite is completed (point A), the center is still at a temperature above the Ms point (point B in Fig. 2b). It is well known that the stresses introduced into a tool by such uneven transformation are dangerous and may lead to warping or cracking.

No matter how severely a carbon steel work-piece is quenched, there probably will be 3 to 7% retained austenite. In other words, even in a drastic quench, some of the austenite will not transform. In general, however, tempering will take care of this and of the stresses created by quenching.

Tempering

The tempering of plain carbon tool steels is a relatively straight-forward operation. The term "tempering" is used to indicate the operation employed to condition the hardened work-piece for use after it has been hardened. There are two prime reasons for conditioning or tempering a tool after hardening; to relieve internal stresses and to transform any residual austenite; together these two factors promote dimensional stability and enhance the physical properties of the work-piece. A secondary reason for tempering is the reduction in hardness caused by increased tempering temperature.

After water quenching, 1% carbon steels may retain 3 to 13% austenite. To insure dimension stability and the utmost in physical properties, this unstable residual austenite should be transformed to a stable product. This is one of the prime objects of tempering.

It has been found that the tempering (by heating) of plain carbon steel takes place in three steps. In the first step, the martensite already present undergoes a slight change which includes a small increase in hardness. If it were to be accurate, the curve in Fig. 3 should show a rise of about 2 points Rockwell C at temperatures between 200 and 300 F. During the second step, much of the residual austenite will transform to a stable form either isothermally at the tempering temperature or on cooling after tempering. The third stage is characterized by rapid softening.

Stages in Tempering Carbon Tool Steels

Stage	Approximate Range, Deg. F	Effect of This Stage
1	180 to 320	Slight shrinkage and increase in hardness
2	450-540	A small expansion, transformation of retained austenite
3	500-675	Larger expansion and softening

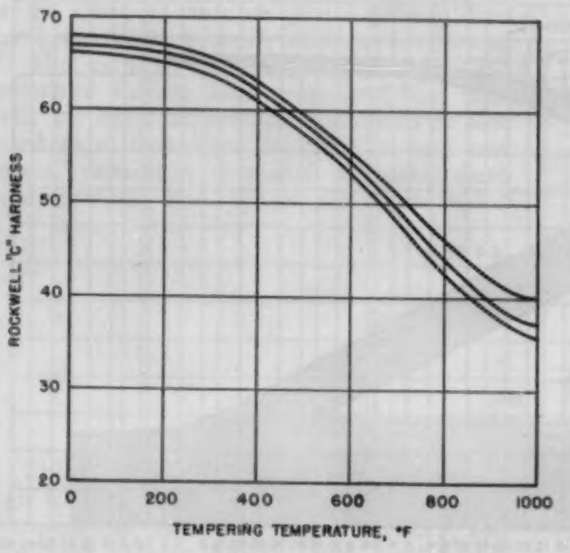


Fig. 3 — Effect of tempering temperature on hardness of 1% carbon tool steel.

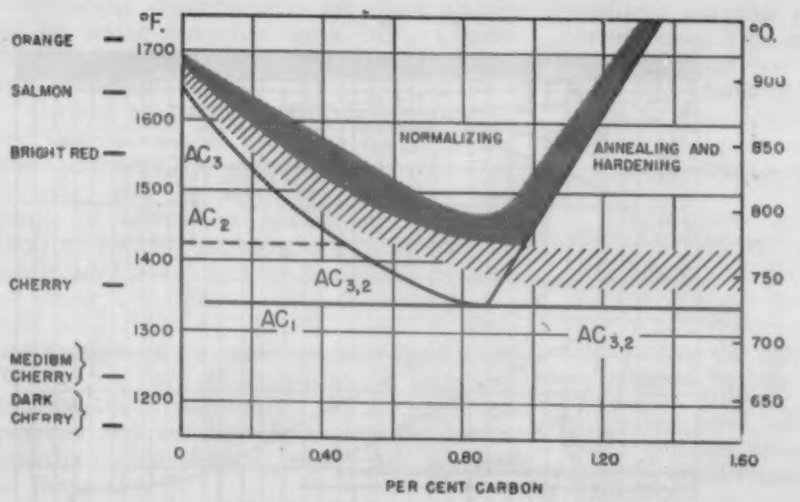


Fig. 4 — Normalizing, annealing and hardening ranges for iron-carbon alloys are shown on this critical range diagram.

The stress relieving occurs in part of each of the three stages. Evidence of the time-dependence of the tempering reactions has been presented by Antia, Fletcher and Cohen. In other words, the above mentioned steps in tempering will occur at lower temperatures if the tempering time is increased. It was mentioned above that from 3 to 13% austenite may remain in water quenched 1% carbon tool steel. Later it was stated that during the second stage of the tempering process residual austenite transformed. However, all of the austenite remaining after quenching does not transform during the tempering by heating. There is another phase of tempering: cooling below room temperature in order to transform the remainder of the austenite.

According to the work of Fletcher and Cohen, virtually complete decomposition of the retained austenite occurs by cooling the steel to between −250 and −260 F if the steel is not allowed to remain more than a few minutes at room temperature between tempering and subzero cooling.

This subzero treatment as a part of the tempering or conditioning of carbon tool steel is not economically feasible except in those cases (such as in the making of gages) where the added dimensional stability (caused by transformation of the austenite) is needed.

Annealing

Annealing is primarily a softening process. All forgings need to be annealed after the hot working operation and any tools or dies that must be rehardened should be annealed before the second hardening operation is performed.

Traditionally, annealing is the slow heating followed by very slow cooling of steel. In a study of the annealing operation and its effects upon steel, Payson has deduced the following rules:

1. The higher the austenitizing temperature, the greater is the tendency for the structure of the annealed steel to be lamellar; the closer the austenitizing temperature is to the critical temperature, the greater is the tendency for the structure of the annealed steel to be spheroidal.
2. To develop the softest annealed structure in steel, austenitize at less than 100 F over the critical temperature

Table 7—Annealing Carbon Tool Steels

Annealing — Slow Cooling[1]	Cycle Annealing
1. Heat uniformly to 1450 F 2. Hold 1 hr. per inch of section 3. Cool slowly in furnace Time required: 12-24 hr.	1. Heat uniformly to 1380[2] F 2. Hold 1 hr.[2] 3. Cool to 1300[2] 4. Hold 2 hr.[2] 5. Air cool Time required: 6-12 hr.

[1] *The same for steels 1-5 (see Table 1)*
[2] *For all in first group except tool steel No. 2; heat No. 2 to 1475 F, hold 2 hr.; cool to 1275 F, hold 4 hr.; and air cool*

Table 8—Tempering Temperatures and Times for Max. Toughness of 1% Carbon Tool Steels

Hardening Temperature F	Tempering Temperatures for Max. Toughness			
	Tempering Time 1 hr.	Tempering Time 4 hr.	Tempering Time 8 hr.	Tempering Time 24 hr.
1400	325	—	—	—
1450	350	325	300	275
1500	375	350	325	300
1550	400	375	350	325
1600	425	400	375	350

Table 9—Summary of Heat Treating Data on Tool Steel No. 6

Hardening Characteristics	A 2-in. dia. piece will harden to 62-63 Rockwell C approximately 3/16 in. deep; core is tough and has a hardness of 40-45 Rockwell C; sizes under 7/8-in. in dia. will harden through; expands during hardening (plain carbon tool steels shrink)		
Tempering Characteristics[1]	Tempering Temperature F	Hardness Rc	Remarks
	As quenched	63.5	(Steel must be protected from decarburization during heat treating)
	200	—	
	300	—	
	400	62	T.S. 290,000 psi.; Y.P. 280,000 psi.; Elong. 5%; Ra 15%
	500	59	T.S. 280,000 psi.; Y.P. 270,000 psi.; Elong. 5% RA 20%
	600	58	T.S. 260,000 psi.; Y.P. 257,000 psi.; Elong. 6; RA 26%
	700	55	T.S. 254,000 psi.; Y.P. 244,000 psi.; Elong. 6.5; RA 30%
	800	50	T.S. 238,000 psi.; Y.P. 227,000 psi.; Elong. ° 0; RA 37%

[1] *Based on tests of 1-3/16-in. dia. by 5-in. annealed samples, water quenched from 1550 F (30 min. at heat) and tempered 1½ hr.*

and transform at a temperature usually less than 100 F below the critical.

3. The time for complete transformation at less than 100 F below the critical may be very long; therefore, if most of the transformation takes place at a higher temperature, where a softer product is formed, and it is completed at a lower temperature, where the time for completion is short, considerable time will be saved.
4. After proper austenitization, the steel can be cooled as rapidly as feasible to desired transformation temperature.
5. After complete transformation at the temperature producing the desired microstructure and hardness, the steel can be cooled to room temperature as rapidly as is desired.
6. To insure a minimum of lamellar pearlite in the structure of 0.70-0.9% carbon steel (and other low-alloy, medium carbon steels) preheat at about 50 F below the critical for several hours and then austenitize and transform as suggested above.

As an illustration of these rules, consider the annealing cycles recommended for carbon tool steels as shown in Table 7.

Normalizing

Many forgings (if they are complicated or "tricky") are normalized and annealed after the forging operation. Fig. 4 indicates the usual normalizing range for carbon tool steel. Cooling from the normalizing heat is usually accomplished in still air.

Medium Alloy Tool Steels

Representative tool steels of this group are listed as the second group in Table 1. For ease in discussion, this group is subdivided into three classes: water hardening, oil hardening and air hardening alloy steels containing less than 5% of any one alloying element.

Water Hardening Medium Alloy Tool Steels

Steel No. 6 is little more than a carbon steel; the combined effects of a slight increase in manganese and silicon plus the presence of about ½ of 1% molybdenum make this a deeper hardening, much tougher steel than any in Group 1. Like other water or brine hardening tool steels, it undergoes some distortion during hardening.

This type of steel has the following applications:

- Long punches and pins
- Heavy duty punches
- Heavy duty forming and bending tools
- Heavy duty coining dies
- Spring collets
- Rivet sets, snaps and busters
- Clutch pins, indexing pins, stops, etc.
- Stamps
- Chisels, screw drivers, mauls, sledges

Pertinent heat treating information is tabulated in Table 9. The rapid finishing steels like No. 7 offer high wear resistance and the ability to maintain a hard, keen cutting edge. The 4% tungsten content of this steel gives it the wear resistance. This steel may be quenched in water or brine.

Typical applications of No. 7 are:

- Burnishing and spinning tools
- Cutting tools for cast irons and nonferrous metals
- Dental burrs
- Fast finishing lathe tools

Table 10—Heat Treating Data, Steel No. 7

Tempering Temp. Deg. F	Hardness-Rc	Remarks
As quenched	66-68	Data obtained from ¾-in. dia. samples, water quenched from 1500 F and tempered 1 hr.; this steel should be preheated to 1200-1250 F prior to austenitizing
300	64-66	
400	63-65	
500	61-63	
600	59-61	
700	55-57	

Annealing Data	
Annealing—Slow Cooling	**Cycle Annealing[1]**
1. Heat uniformly to 1450 F 2. Hold as desired 3. Cool slowly in furnace	1. Heat uniformly to 1600 F 2. Hold 16 hr. 3. Cool to 1320 F 4. Hold 4 hr. 5. Cool to 1300 F 6. Hold 2 hr. 7. Air cool (Resulting hardness: 217-229 BHN

[1] *See also Fig. 5*
[2] *This steel will be very soft if held at the austenitizing temperature a long time as the residual carbides agglomerate, making for a coarse, machinable structure*

Table 11—Heat Treating Data, Steel No. 8

Hardness, Rc			Annealing Data	
Tempering Temperature, Deg. F	Water Quenched[1]	Oil Quenched[2]	Annealing—Slow Cooling	Cycle Annealing[3]
As quenched	64-65	61-63	1. Heat uniformly to 1475 F	1. Heat to 1475 F
300	60-61	60-61	2. Hold 1 hr. per in. of section	2. Hold 2 hr.
400	59-60	58-60	3. Cool slowly in furnace	3. Cool to 1275 F
500	59-60	58-59		4. Hold 4 hr.
600	57-58	57-58		5. Air cool
700	56-57	56-57		
800	51-52	51-52		
900	48-49	47-48		
1000	44-45	44-45		

[1] *from 1600 F* [2] *from 1650 F* [3] *See also Fig. 6*

Table 12—Heat Treating Data, Steel No. 9

Hardness, Rc			Annealing Data	
Tempering Temperature Deg. F	Water Quenched[1]	Oil Quenched[2]	Annealing—Slow Cooling	Cycle Annealing
As quenched	59-60	55-56	1. Heat uniformly to 1450 F	1. Heat uniformly to 1425 F
400	55-56	53-54	2. Hold 1 hr. per in. of section	2. Hold 2 hr.
500	53-54	52-53	3. Slow cool in furnace	3. Cool to 1310 F
600	51-52	50-51		4. Hold 4 hr.
700	48-49	47-48		5. Air cool
800	45-46	42-43		
900	41-42	40-41		

[1] *from 1650 F* [2] *from 1525 F*

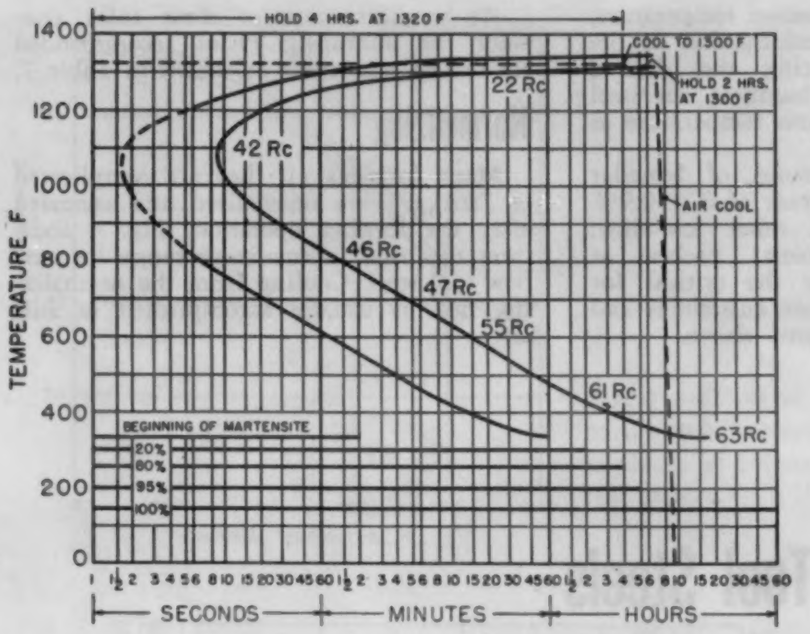


Fig. 5—T-T-T curve for 1.30% carbon, 3.50% tungsten steel (similar to steel No. 7, table 1). Cycle anneal is shown by dotted lines (see also table 10); direct transformation hardening, interrupted quenching and martempering cycles can be calculated from this curve.

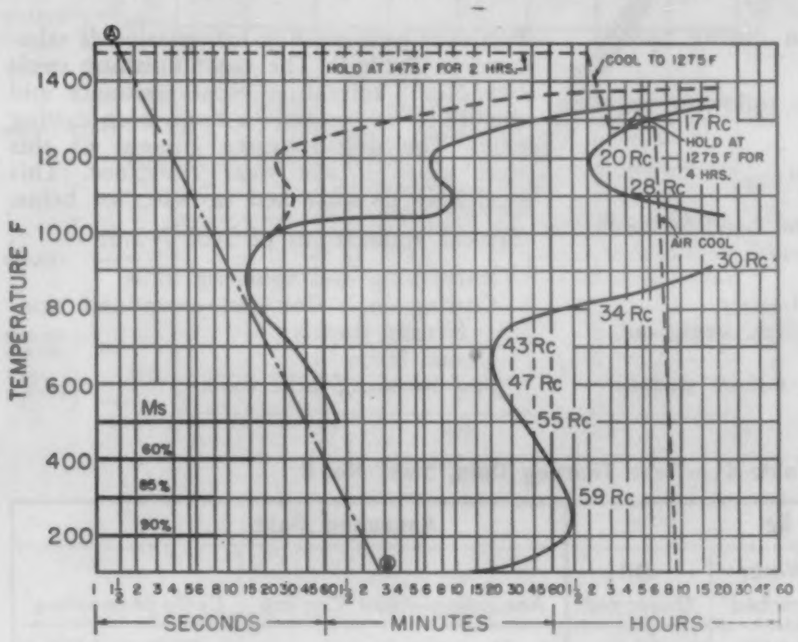


Fig. 6 — T-T-T curves for steel No. 8 showing cycle anneal. There is a lapse of 15 sec. before transformation starts. Curve A-B represents slowest cooling that will produce practically complete hardening (app. 12 deg. per sec.).

Shaving and drawing dies

Hardness and tempering data are tabulated in Table 10.

The next of this sub-group of medium alloy, water hardening types is represented by steel No. 8. This, like No. 6, can be quenched in water or oil (simple shapes and large sections are water quenched; smaller sections can be oil quenched). Toughness at relatively high hardness is its outstanding quality; it also has good resistance to impact. Its field of use is much the same as for steels like No. 6.

Heat treating data for this type of steel may be obtained from Table 11 and Fig. 6. From the T-T-T curves in Fig. 6 the reason for the similarity of water and oil quenched hardness values given in Table 11 are apparent: even relatively slow cooling will produce almost complete hardening.

Another in this sub-group of water-oil hardening, very tough tool steels is No. 9. The predominating alloy in this steel is chromium, making it a tough, heat resistant steel suitable for either hot or cold work application. Simple shapes can be water quenched; oil is used for quenching the more complicated parts. The oil and water quenched hardnesses and the heat treating data are included in Table 12.

Steel No. 10 is a chisel steel. Its high silicon and molybdenum contents contribute to its ability to resist shock and impact and abrasive wear. Like the others of this subgroup, this is a very tough steel. It is a cold work material having the following applications:

- Chisels
- Punches
- Feed fingers, pins, etc.
- Heavy duty forming and bending tools
- Heavy duty perforating punches
- Rivet sets and busters
- Stamps
- Spring collets
- Flaring tools

The heat treating data and physical properties are listed in Table 13.

Oil Hardening Medium Alloy Steels

This subgroup is made up of the popular oil hardening, non-deforming die steels. These are deep hardening steels that depend upon manganese, chromium, or chromium and tungsten for their depth of hardening qualities. They are less resistant to damage from impact than are the shallow hardening carbon tool steels because they lack the tough core. Their slower transformation rate makes for much less distortion in hardening than any steels above them in Table 1.

Some of the applications of these steels are:

- Dies (blanking, trimming, forming, coining, etc.)
- Gages
- Thread rolling dies
- Reamers and taps
- Burnishing gears
- Hot heading and swaging dies, small drop forge dies (Nos. 13, 15 and 16).

Steels 13, 15 and 16 are hot work steels and can be used for either cold or hot work applications. Steel No. 15 is sometimes carburized when high wear resistance

Table 13—Heat Treating Data, Steel No. 10

Tempering Temperature[1]	Hardness, Rc	Physical Properties at Various Hardness Values: T.S., psi	YP, psi	Izod, ft-lb.	Elong. %	Red. in A, %	Variation in Hardness with Quenching Medium and Temp.: Quenching Temp.	Medium Quenching	Hardness, Rc
Annealed	18	101,000	78,000	—	32.5	63.0	1575 F	Water	62
As quenched	61-62	368,000	294,000	6.0	5.9	16.3	1600	Water	61-62
400 F	59	333,000	258,000	7.0	6.5	20.0	1625	Water	60-61
500	58	330,000	251,500	8.0	5.2	25.0	1625	Oil	57
600	57	395,000	256,000	8.5	6.0	28.0	1650	Oil	57-58
700	55-56	306,000	245,000	9.1	8.0	35.0	1675	Oil	58
800	52	260,000	208,000	9.6	9.9	38.2			
900	47-48	238,000	190,500	10.0	10.8	41.0			
1000	46-47	226,000	181,000	10.1	11.9	43.2			
1100	43-44	202,000	163,500	11.6	13.0	45.6			

[1] *Tempered 1 hr. after quenching from 1600 F*

Table 14—Hardness Values—Oil Hardening, Medium Alloy Steels (Nos. 11-16)

Tempering Temperature, F	Hardness, Rc				
	Steel No. 11	Steel No. 13	Steel No. 14	Steel No. 15	Steel No. 16
As quenched	63-65	64-66	65	58-60	60-61
200	63-65	—	—	—	—
300	63-65	—	64-65	58-60	58
400	60-63	—	62-64	57-59	57
500	58-60	—	57-60	—	56
600	54-57	—	53-56	56-58	55
700	50-53	61-63	—	—	54
800	48-50	60-62	—	55-57	53
900	43-45	59-61	—	—	52
1000	39-41	57-59	—	52-54	51
Condition	Oil quenched from 1475 F and tempered 1 hr.	Oil quenched from 1750 F and tempered 4 hr.	Oil quenched from 1600 F and tempered[1]	Oil quenched from 1750 F and tempered 4 hr.[2]	Oil quenched from 1700 F and tempered

[1] *Size of test piece 2x1½x2 in.* [2] *Size of test piece 4½-in. dia. x 3-in. long*

Table 14A—Length Changes (in 4 in.) After Hardening and Tempering, Steel No. 11

Quenching Temp., F	Tempering Temperatures						
	As quenched	200	300	400	500	600	700
1550	+0.003	+0.002	0 in.	—0.0005	+0.004	+0.002	+0.002
1500	+0.004	+0.003	+0.001	+0.001	+0.004	+0.003	+0.002
1450	+0.003	+0.002	+0.001	+0.0005	+0.003	+0.002	+0.001

Table 15—Room Temperature Hardness of Air Hardened Steels

Tempering Temp., F	Steel Number				
	17	18	19	20[1]	20[2]
As quen.	51-53	53-55	48-49	62-64	63-64
1000	52-54	51-53	49-50	57-58	58
1050	45-47	48-50	48-49	56-57	58
1100	40-42	45-47	47-48	54-55	—
1150	35-37	37-39	43-45	51-52	—
1200	30-32	28-30	39-40	47-48	—

[1] *Air cooled from 1825 F*
[2] *Oil quenched from 1830 F*

Table 15A—Average Hardness at Elevated Temperatures

Temp. at Which Hardness Was Measured, F	Steel No. 18[1]		Steel No. 19[2]	
	Tempered to		Tempered to	
	444 BHN	387 BHN	444 BHN	388 BHN
500	395	330	—	—
600	385	325	—	—
700	380	320	—	—
800	365	310	325	315
900	360	310	335	315
1000	345	295	315	285
1100	270	245	295	270
1200	170	190	190	190
1300	—	—	140	155

[1] *Air cooled from 1800 F and tempered to produce hardness values of 444 and 387 BHN*
[2] *Air cooled from 1650 F and tempered to produce hardness values of 444 and 388 BHN*

combined with great core strength is needed.

Air Hardening Medium Alloy Tool Steels

The last subgroup of the medium alloy tool steels is that devoted to the slowest rate and therefore, show the least distortion after hardening. Steels No. 17-21 all contain approximately 5% chromium except No. 21 which contains 2% each of manganese and chromium; in addition, about 1% molybdenum is present in each; these are the elements that give these steels their air hardening characteristics.

The outstanding characteristics of each of these steels are:

Steel No.	*Characteristics*
17	A tough, medium red-hard hot work steel that is resistant to heat checking and cracking (when water cooled in service)
18	A bit tougher hot work steel than No. 17 and is very resistant to heat checking and cracking from use of coolants
19	Another hot work steel having a good combination of red-hardness and toughness
20	A cold work die steel having very low distortion during hardening
21	A less common, cold work, air hardening steel that is a modification of the 1% carbon, 5% chromium type (No. 20); the replacing of some of the chromium in type 20 by manganese gives this steel a lower hardening temperature and a somewhat wider hardening range at a slightly lower peak hardness.

The first three steels in this subgroup are hot work steels and are used for extrusion, forging, gripper, header and piercing dies, punches, hot billet shears, etc. The last two are cold work steels, the former type being more common. Steel No. 20 has high toughness and wear resistance and this type is used for thread rolling dies, blanking, drawing and forming dies, punches and rolls.

The hardness and tempering values of these steels are contained in Table 15.

High Alloy Tool and Die Steels

The third major division of tool steels is the high alloy class; this includes those tool and die steels that contain over 5% of any one alloying element and, in general, there are several alloying elements present in these steels. All of these are either oil or air hardening.

Hot Work High Alloy Die Steels

Steels of types represented by types 22 through 29 (Table 1) are largely used in hot work applications. The first one in this group No. 22 is a low carbon, medium tungsten hot work steel. Its outstanding quality is its red-hardness. Dies made of this steel can operate successfully at a dull red heat without softening or showing excessive wear. The combination of 3% chromium and 9% tungsten impart red-hardness qualities to this steel only slightly lower than those of high speed steels.

This steel may be quenched either in oil or air; the room temperature and elevated temperature hardness values developed after quenching in both media are listed in Table 16 and 16a. A typical hardening cycle for large dies that are oil or salt bath quenched is:

1. Preheat to 1500 to 1550 F
2. Austenitize at 2100 F
3. Quench in oil or salt bath to 1000 F
4. Air cool to below 300 F
5. Temper as needed

Fig. 7, the T-T-T curves graphically depict the hardening characteristics of this type of steel. From these curves it is evident that a die must be cooled from its

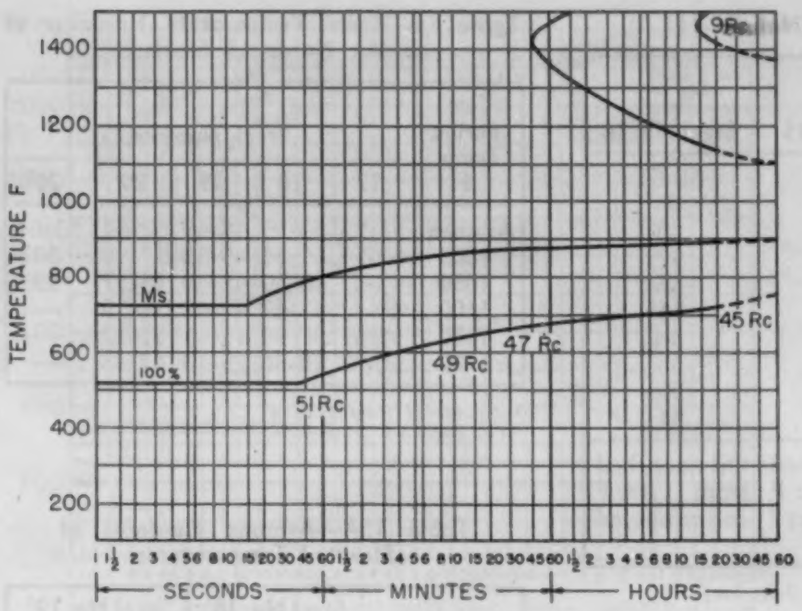


Fig. 7 — This curve shows that when steel No. 22 is quenched from 2100 F it must be cooled below 1400 F in less than 45 min. When the steel is cooled below 500 F transformation is practically complete and the steel is fully hardened.

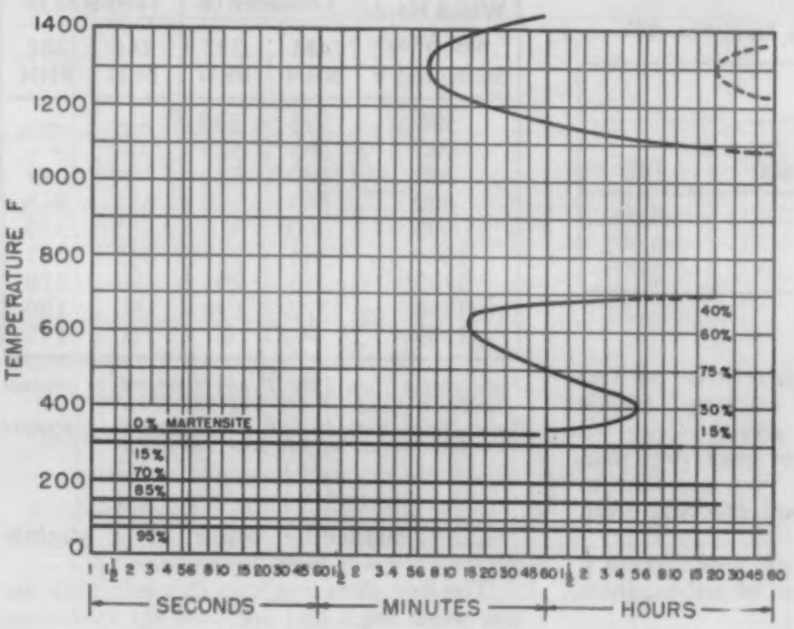


Fig. 8 — When steel No. 25 is air cooled from 1800 F it must be cooled to below 1300 F in less than 7 min. Even on cooling to room temperature this steel retains some austenite.

Table 16—Room Hardness Values for Various Hardening Tempering Temperatures—Steel 22

	Hardness, Rc			
Hardening Temperature	**2000**	**2050**	**2150**	**2250**
Tempering Temperature, Deg. F	**Oil Quenched**[1]			
As quenched	45.5-49.0	44.5-48.5	48.0-41.0	50.0-52.0
950	46.5-49.5	46.0-49.5	50.0-52.0	51.5-53.5
1000	48.0-50.5	47.5-50.5	50.5-52.5	52.5-54.5
1050	49.5-51.5	49.0-51.5	52.5-54.5	53.5-55.5
1100	49.0-51.0	48.5-50.5	51.0-53.0	52.5-54.5
1150	42.5-44.5	43.0-45.0	44.5-46.5	46.5-48.5
1200	36.0-38.0	36.5-38.5	40.5-42.5	43.5-45.5
1250	29.5-31.5	30.0-32.0	34.5-36.5	35.0-37.0
	Air Cooled[1]			
As quenched	43.0-45.0	43.5-45.5	44.5-46.5	45.0-47.0
950	43.5-45.5	44.5-46.5	46.0-48.0	46.5-48.5
1000	44.5-46.5	45.5-47.5	47.0-49.0	47.5-49.5
1050	48.0-50.0	48.5-50.5	50.0-52.0	50.5-52.5
1100	38.5-50.5	49.5-51.5	51.0-53.0	53.0-55.0
1150	42.0-44.0	44.5-46.5	46.0-48.0	48.5-50.5
1200	38.5-40.5	36.0-38.0	39-0-41.0	41.0-43.0
1250	26.5-28.5	29.5-31.5	31.5-33.5	33.5-35.5

[1] *Size of test piece 4x4x3-in.*

austenitizing temperature (approx. 2100 F) to below 1400 F in less than 45 min. in order that high temperature transformations be avoided. The curve also shows that the Ms point (temperature at which martensite begins to form) is slightly below 700 F and the transformation is practically complete at about 500 F.

This diagram also emphasizes the need for not starting the tempering operation until the work-piece has cooled almost to room temperature (at least until it has cooled below 300 F). If, for example, the die is removed from the quench (or its cooling is interrupted by placing it in a tempering furnace) while it is still hot (say about 600 F) the austenite that would have transformed in cooling from 600 to 500 F will be prevented from undergoing the change from martensite. Then, when the die is cooled from the tempering heat, the delayed transformation will take place producing untempered martensite which will nullify the purposes of tempering (i.e.—residual stresses will be present). In the case of a delicate die, this can seriously shorten its useful life.

A list of typical uses for this type of steel would be:

- Brass forging dies
- Extrusion dies and mandrels (when not water cooled)
- Hot punches, coining and trimming dies
- Nut pinches and piercers
- Swaging dies
- Small gripper dies

The next type of hot work steel is represented by No. 23. This is a medium carbon steel containing more tungsten (13%) than No. 22 and about the same amount of chromium. This higher tungsten content increases the resistance to abrasion as well as the red-hardness. The toughness of this steel is somewhat less than that of type 22.

Some of the applications for this type of steel are:

- Punches
- Hot die inserts
- Hot drawing and forming dies
- Extrusion dies
- Shear blades

The hardness values for various tempering temperatures are given in Table 17. The values for both oil and air quenched

Table 16a—Hardness at Elevated Temperatures—Steel No. 22

	Hardness, BHN	
Temperature at Which Hardness Was Measured, Deg. F	**Tempered to**	
	444 BHN	**388 BHN**
500	420	390
600	420	375
700	405	345
800	390	305
900	375	295
1000	345	280
1100	330	270
1200	305	250
1300	250	220
1400	165	165
1500	125	125
1600	105	100

samples are included in this table. The secondary hardening effect is noticeable in these steels, having a peak between 1000-1100.

A steel combining some of the desirable qualities of both the chromium (Nos. 17, 18, 19 and 20) and tungsten (Nos. 22 and 23) hot work steels is represented by No. 24, a chromium-tungsten die steel that is suitable for either hot or cold work applications and which may be oil- or air-quenched. The higher chromium content of this steel makes it resist scaling to a greater degree than the tungsten hot work types.

A steel of the composition shown in Table 1 (No. 24) would be used in making dies, grippers and headers for hot forging.

The 1% carbon chromium-molybdenum air hardening steel represented by No. 25 is intermediate in abrasion resistance between oil hardening and high carbon, high chromium steels. It has greater toughness than either of these other two types and has good machinability. Another feature of this type of steel is its small size change during hardening.

With this characteristic, 1% carbon chromium-molybdenum steels are used for:

Blanking, coining, forming, trimming and lamination dies
Punches
Shear blades
Thread rolling dies
Gages

As noted above, this type of steel has favorable machining characteristics and in this respect it compares as follows with some other tool materials:

Material	*Machinability*
Carbon tool steel	100
Oil hardening tool steel	81
1% carbon chromium-tungsten steel	74
High carbon, high chromium	66

There are several possibilities for hardening this type of steel. The first is:

1. Preheat at 1450-1500 F
2. Austenitize at 1775-1825 F
3. Air cool

Or an interrupted quench process can be used on large or complicated parts:

1. Preheat at 1450-1500 F
2. Austenitize at 1750-1800 F
3. Quench into oil and remove when cooled to 1000-1100 F (or quench into a salt bath at 1000 F)
4. Air cool

Table 17—Room Temperature Hardness of Type 23 Hot Work Die Steel

Tempering Temperature, Deg. F	Hardness Rc			
	Oil Quenched From		Air Cooled From	
	2000	2200	2000	2200
As quenched	50	50	46	49
900	52	54	49	50
1000	53	56	53	54
1100	52	56	51	54
1200	49	53	49	52

Table 18—Hardness Values for Steel 25

Tempering Temperature,[1] Deg. F	Hardness, Rc
As quenched	63-64
350	62-63
400	61-62
500	59-60
600	57-58
700	57-58
800	56-57
900	57-58
1000	57-58

[1] *After air cooling from 1800 F; tempering time 3 hr.; size of test piece 4x4x3-in.*

Another hardening method that can be used with this type of steel involves nitriding. The steps in this process are:

1. Preheat at 1450-1500 F
2. Austenitize at 1900 F
3. Air cool
4. Temper (two hours min.) at 1000 F
5. Grind
6. Nitride at 950-975 F (15 hrs. will produce a case 0.005 in. deep and 72 hrs. will give a 0.015 in. case)
7. Air cool—surface hardness should be 900-1100 Vickers (Rc 67 C and over) and core hardness 54-57 Rockwell C

Tempering should not be started until the work-piece has been cooled at least to 150 F; the 95% martensite line is at less than 100 F (see Fig. 8), hence residual austenite may be present to transform to untempered martensite during cooling from the tempering heat unless care is exercised. The hardness-tempering data for this type of steel are presented in Table 18.

The 1.5% carbon, high chromium air hardening type die steel, No. 26, is known for its resistance to abrasive wear. Like steel No. 25, this material can be oil quenched from a slightly lower temperature than that employed when air cooling; the size change (although small) is larger when oil quenched than when hardened in air.

The uses for steels of this classification are much the same as for steel No. 25 with the addition of such items as burnishing tools and lathe centers.

The techniques employed in hardening are quite similar to those described for the tungsten-chromium steel No. 25. See Table 19 for hardness after various tempering temperatures.

Steel No. 27 is similar to No. 26 except that it contains considerably more carbon than does the latter. For this reason, steel No. 27 is more brittle and less machinable than its lower carbon counterpart. Its uses (it is a cold work steel) are much the same as for No. 26 except that its greater brittleness must be considered. The wear resistance of this high carbon, high chromium steel is approximately six times that of plain carbon tool steel. With such a high percentage of chromium, this type of steel is resistant to oxidation at high temperatures and to staining and corrosion. As is to be expected with this type of steel, it can either be air- or oil-hardened. (See Table 20 for the hardening data for this steel).

In an effort to improve the toughness (overcome the brittleness) of the straight high carbon, high chromium steel, additions of silicon and tungsten were made (see steel No. 28). The heat treatment and applications of these steels are much the same as those for steel No. 27.

Table 19—Hardness Values for Steel 26

Tempering Temperature,[1] Deg. F	Hardness, Rc
As quenched	62-63
300	62-63
400	61-62
450	60-61
500	59-60
600	59-60
700	58-59
800	58-59
850	58-59
950	59-60
1000	56-57
1050	52-53

[1] *After air cooling from 1800 F and tempering 3 hr.*

Table 20—Heat Treating Data for High Carbon, High Chromium Steel No. 27

Heat Treating Cycles	
Air Cool	Interrupted Quench
1. Preheat to 1450-1500 F	1. Preheat to 1450-1500 F
2. Austenitize at 1800-1850 F	2. Austenitize at 1750-1800 F
3. Air cool	3. Quench in oil (or salt bath at 100-1100 F) and remove from oil at 100-1100 F
4. Temper	4. Air cool
	5. Temper

Table 21—Hardness of Steel No. 29

Tempering, Temperature,[1] deg. F	Hardness after Tempering, Rc
As quenched	56-58
1000	56-58
1050	53-55
1100	48-50
1150	45-47
1200	41-43

[1] *After cooling in air from 1950 F (tempered 2 hr.)*

Table 21a—Hardness at Elevated Temperatures, Steel No. 29

Temperature at which Hardness was Measured, deg. F	Tempered to	
	444 BHN	387 BHN
500	395 BHN	355 BHN
600	390	350
700	380	335
800	370	330
900	365	320
1000	340	310
1100	305	260
1200	220	195
1300	160	135
1400	120	95

The last steel (No. 29) in this group is an intermediate tungsten hot work die steel. It is an air hardening steel possessing medium red-hardness and toughness qualities. The applications for this steel include:

Backer blocks, die holders, ejector and pushout rings
Brass extrusion dies
Gripper dies (for upsetting steel)
Press forging dies and inserts for brass

This being a straight air hardening steel, its hardening and tempering operations are not difficult. The hardness values at room and elevated temperatures after hardening and tempering are listed in Table 21.

High Speed Steel

The hardening of high speed steels has been studied in all its phases and ramifications. The knowledge of the hardening process; the structural changes produced by heating and quenching, isothermal transformations, and conditioning (tempering and subzero treatment) have been increased in recent years. Even so, all the art has not yet been taken out of hardening.

The high speed steels listed in Table 1 (Nos. 30-39 inclusive) are representative types. These are the most common analyses; there are, of course, many others but these are generally variations or slight modifications of those presented in Table 1.

Type No. 30 is the old standard high speed steel, 18% tungsten, 4% chromium and 1% vanadium. High red-hardness is the outstanding characteristic of high speed steels and this type combines this with good toughness qualities.

High speed steels are essential tool materials; metal cutting tools such as drills, taps, reamers, milling cutters, lathes, shaper and planer tools and similar items are the chief applications for this type of steel.

Hardening

Since high speed steels must be heated to such high temperatures for hardening (2300-2400 F), precaution must be taken against decarburization and scaling during heat treatment. Salt baths or controlled atmosphere furnaces are generally employed for this type of hardening.

Preheating is usually carried out in one or two stages depending upon the complexity of the tool (the two stage treatment being for the more complicated tools). The time at high heat must be as short as possible to avoid grain-growth and decarburization and yet long enough to insure uniformity of temperature throughout the area to be hardened and to make sure that the proper degree of solution of carbides takes place. The higher the austenitizing temperatures, the more complete is the solution of carbides and the greater the hardness and lower the toughness of the quenched tool.

High speed steels of this type may be quenched in oil, salt bath or air. An interrupted quench is often employed for tools of any size or complexity. Typical cycles are given in Table 22. The temperature of the quench has considerable bearing on the subsequent tempering operation as can be seen by looking at Fig. 9 which is the T-T-T curves for 18-4-1 type of high speed steel. If the steel is quenched into hot oil, at, say, 300 F, it can be seen from Fig. 9 that this temperature corresponds to approximately 40% transformation. In other words, quenching to 300 F leaves approximately 60% of the austenite untransformed. To insure the highest physical properties in the tool, all this residual austenite must be transformed in the tempering operation.

If the tool is quenched into a molten salt bath at 1100 F, no transformation will take place at this temperature (see Fig. 9); then after equalization of the temperature throughout the work piece, it can be air cooled to room temperature with little chance of cracking or distortion. The residual austenite from this method of hardening may run as high as 25% (note that the 80% transformation line is slightly below 100 F on Fig. 9). Quenching directly in air or oil from the hardening heat will not produce a much greater percentage change to martensite; the tempering of high speed steel is of considerable importance.

A method for making extreme hardness in small sections of tool steels has been described by McIntyre. By using this treatment (detailed in Table 22a) high speed steels of both the tungsten and the molyb-

Table 22—Tempering Data—High Speed Steel, No. 30

After Oil Quenching From 2350 F

Tempering Temperature	Cycle	Hardness, Rc
As hardened		66
1000 F	Single temper, 5 hr.	65
1050	Single temper, 5 hr.	65
1050	Double temper, 5 hr.*	64
1075	Double temper, 4 hr.	64
1100	Double temper, 4 hr.	63

** Total time at tempering temperature 5 hr. (2½+2½ hrs.)*

Conditioning by Tempering and Subzero Cooling

Treatment A*	Treatment B**
1. Oil quench from 2350 F	1. Oil quench from 2350 F
2. Allow parts to cool to about 300 F in oil after quenching	2. Cool to about 200 F in oil after quenching
3. Cool to —120 F and hold for 6 hr.	3. Place in cold chamber and cool to −120 F for 1 to 2 hr.
4. Warm to room temperature	4. Warm to room temperature
5. Temper at 1050 F for 3 hr.	5. Temper at 1050 F for 2 hr.
6. After cooling from 1050 F cool to −120 F for 6 hr.	6. Cool to room temperature
7. Warm to room temperature	7. Retemper at 1050 F for 1 to 2 hr.
8. Retemper at 1050 F for 3 hr.	

** From Berlien, G. B., "Subzero Hardening Cycles," Steel, Jan. 10, 1944*
*** Suggested by Jessop Steel Co.*

Salt Bath Hardening and Tempering Cycle

1. Preheat at 1100 F (optional—depending upon complexity of tool)
2. Second preheat at 1550 F
3. Austenitize at 2200-2400 F
4. Quench to 1100 F (hold until equalized)
5. Cool in air to room temperature
6. Double temper at 1050 F

Table 22a—Cyanide Treatment for High Speed Steels[1]

Process
1. Heat work-piece in molten sodium cyanide at 1450 F for 1½ hr.
2. Cool in air
3. Wash off cyanide
4. Heat to 2250-2300 F
5. Quench in oil
6. Double temper at 1050 F for 1 hr. intervals
Resulting hardness: Rc 68-70

[1] Both tungsten and molybdenum high speed steels can be treated by this process

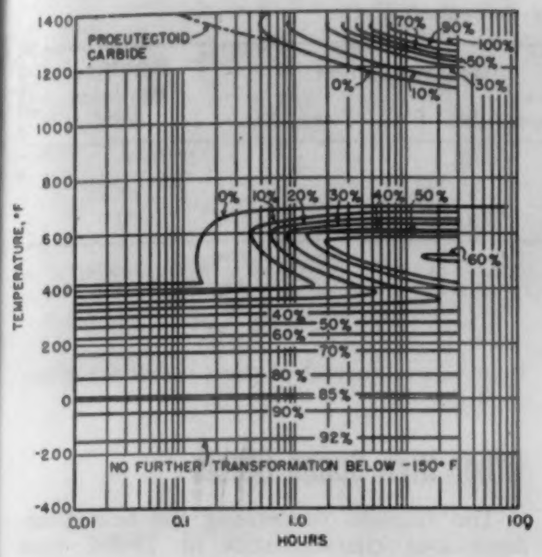


Fig. 9—T-T-T curve for 18-4-1 high speed steels (No. 30) shows transformation characteristics after being quenched from 2350 F. Transformation is not complete even after cooling to room temperature; either double tempering and/or subzero cooling is necessary.

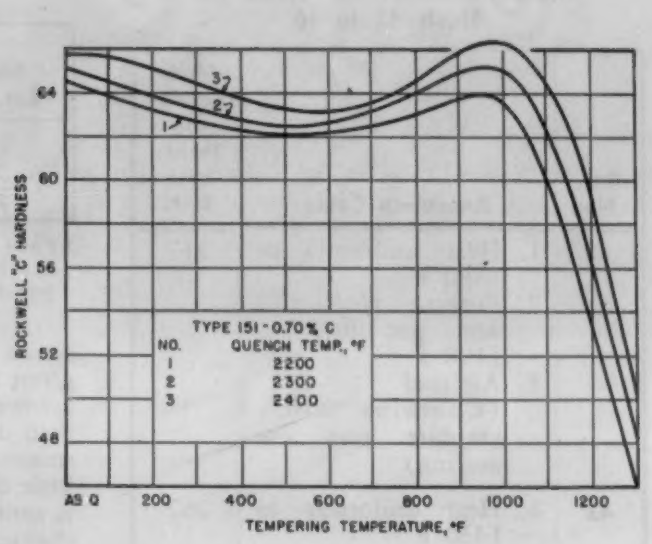


Fig. 10—Austenite-martensite transformation curves for 18-4-1 high speed steel at temperatures lower than of room.

denum types can be hardened through (if not more than 1-in. in cross section) to hardnesses of 68-70 Rockwell C and that work-pieces so heated retained these hardness values up to 1150 F. When this treatment was applied to small tools like lathe tool bits where brittleness is not a detrimental factor, the life is increased.

Tempering

It has been shown that high speed steel softens slightly during tempering within the range of 500 to 700 F and that a secondary hardening reaction occurs if the tool is tempered at 1000-1050 F, see Fig. 10. Cohen and Koh have explained these phenomena on the basis of some complex time-temperature dependent changes and they have determined that . . . "Little if any, residual austenite transforms at the tempering temperature. Instead it transforms into martensite during cooling. . . . The amount of austenite which thus transforms and the temperature at which this transformation begins during cooling depends principally upon the time and temperature of tempering, assuming constant hardening conditions, and seem to be independent of the cooling rate unless the latter is rapid enough to introduce quenching stresses."

This transformation of residual austenite on the cooling down from the tempering heat leaves the tool with an appreciable percentage of untempered (and hence highly stressed) martensite. A second temper will relieve these stresses and temper the newly transformed martensite where a

Table 23—Comparison to Common High Speed Steels Nos. 30-39

Ref. No.	Characteristics	Typical Applications
30	Easy to harden, has good red hardness and toughness properties	General purpose metal cutting tools
31	Has greater wear and abrasion than No. 30; Holds a sharp, keen cutting edge and is tough	Circular and flat form tools, and finishing tools, reamers and broaches for cutting hard materials
32	High toughness	Cutting tools subject to intermittent cuts and for heavy duty cutting of hard alloys or gritty material
33	The 5% cobalt gives greater red hardness, good wear resistance and lower toughness than No. 30.	Used for rough cutting single point tools and for dry machining cast iron and non-ferrous alloys
34	Its toughness, abrasion resistance and red hardness are greater than those of No. 30, combines good points of Nos. 32 and 33	For heavy duty single point cutting tools; for machining stainless steels
35	Great resistance to abrasion	Cutting tools for machining usually hard and/or gritty materials such as chilled cast iron, manganese steel, heat treated steels, etc.
36	Red-hardness and toughness about same as for No. 30	Used as a tungsten-saving alternate for No. 30
37 & 38	Tough and have good cutting characteristics	Most widely used molybdenum high speed steels; used for both single and multiple point tools
39	Has a wider hardening range than other molybdenum high speed steels—it is very tough and has high red-hardness properties	General purpose, tungsten conserving tool steel

Table 24—Heat Treating Characteristics, Steels 42 to 46

Ref. No.	Heat Treatment	Tempering Temperature, deg. F	Hardness Rc
42	Oil quench from 1470 F (0.394 in. sq.)	300 500 700 900 1100	64 61 53 46 36
43	Water quenched from 1450 F (0.394 in. sq.)	As quenched 250 300 400 700	68-69 67-68 65-66 63 54-55
44	Water quenched from 1450 F (0.394 in. sq.)	As quenched 300 500 700 900 1100	67-68 66 62 54 44 32
45	Air hardened from 1550 F (0.394 in. sq.)	As quenched 300 500 700 900 1100	63 61 56 54 53 41
46	Water quenched from 1450 F (0.394 in. sq.)	300 500 700 900 1100	65 61 54 43 35
	Air cooled from 1400 F	As quenched	26
	Air cooled from 1470 F (0.394 in. sq.)	As quenched	28

Table 25—Annealing Cycles for Steels 42 to 46

Ref. No.	Annealing Cycle	Max. Resulting Hardness, BHN
42	1. Heat uniformly to 1480 F 2. Furnace cool (20 deg. per hr.) to 1100 F 3. Air cool (Contains 0.50% graphite after annealing)	217
43	1. Heat uniformly to 1430 F 2. Furnace cool (20 deg. per hr.) to 1100 F 3. Air cool (Contains 0.30% graphite after annealing)	262
44	1. Heat uniformly to 1380 F 2. Furnace cool (20 deg. per hr.) to 1150 F 3. Air cool (Contains 0.20% graphite after annealing)	207
45	1. Heat uniformly to 1500 F (soak 4 hr.) 2. Furnace cool (20 deg. per hr.) to 1000 F (hold 4 hr.) 3. Air cool (Contains 0.30% graphite after annealing)	262
46	1. Heat uniformly to 1380 F 2. Furnace cool (20 deg. per hr.) to 1150 F 3. Air cool (Contains 0.70% graphite after annealing)	212

Table 26—Short Time Annealing Cycles[1]

Steel Ref. No.	Austenitizing		Transformation		Resulting Hardness BHN
	Tem., deg. F	Time, hr.	Tem., deg. F	Time, hr.	
26	1700	2	1430	4	223
30	1650	2	1400	4	255
39	1650	2	1400	4	217

[1] *These cycles are those that produce a reasonably low hardness in a minimum of time; cooling from austenitizing to transformation temperature can be rapid; all work can be air cooled at end of transformation period*

single, long period temper will not. Parts given a multiple tempering treatment have a lower hardness by ½ to 1 Rockwell C than do single tempered tools, but internal stresses are almost totally relieved, there is little or no retained austenite (the material is quite stable—i.e., it will not "age" and change its dimensions) and its toughness is considerably greater.

Residual austenite can be transformed directly after quenching and cooling to room temperature by continuing the cooling on down to —120 F to —150 F. In general, however, the transformation obtained by this method is about equal to that obtained by multiple tempering. In short, retained austenite can be completely transformed by multiple temperings or by several alternate subzero and tempering (at 1050 F) treatments. Several of these cycles are given in Table 22.

Other High Speed Steels

The remarks concerning the heat treatment and characteristics of 18-4-1 type high speed steel (No. 30) apply equally to most of the other high speed steels in this subgroup. Of course, the austenitizing temperatures vary and there are special techniques employed in the hardening of molybdenum high speed steels. The use of rectified salt baths for a hardening medium means that all high speed steels can be handled alike except for temperatures. Table 23 lists these steels comparatively, indicating their characteristics and applications.

Miscellaneous Tool Steels

The tool materials in the last group are divided into two subgroups. The first is made up of low carbon very soft and uniform steels (or die irons) for making dies for plastic articles. Type No. 40 has good hobbing qualities and usually is carburized and oil quenched; the resulting hardness should be approximately Rockwell 60 C. When annealed this material is dead soft (BHN 100) and it takes a high polish.

Steel No. 41 represents a medium carbon, low alloy type of die steel. For making plastic molds, this steel is carburized and hardened. Die casting dies are made of this material in a heat treated condition (usually BHN 197-225) although the steel can be tempered to produce other hardness values up to Rockwell 36.5 C (BHN 340).

The second subgroup is made up of graphitic steels. These contain free carbon (graphite) and thus combine some of the properties of cast iron and medium alloy tool steels. The presence of the graphite in these steels adds to their wear and scuffing resistance (and freedom from pick-up) and machinability. The important applications for these steels are dies, gages, forming, spinning, edging rolls, molds, and parts subject to wear or scuffing. The hardening characteristics are listed in Table 24.

Acknowledgement

The author acknowledges with thanks the assistance given by the following individuals and organizations in the preparation of this manual:

Mr. Gordon S. Tuthill, Advertising Mgr., and Mr. C. G. Merritt, Crucible Steel Co. of America.

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Timken Steel Company, Canton, Ohio

Jessop Steel Company, Washington, Pa.

Bethlehem Steel Company, Bethlehem, Pa.

The following publications were consulted while gathering information for this manual:

Gill, Rose, Roberts, Johnstin and George, "Tool Steels", Am. Soc. Metals (1944).

"Metals Handbook", Am. Soc. Metals (1939).

Morris Cohen & Paul Gordon, "Heat Treatment of High Speed Steels", *Iron Age*, Vol. 157, Nos. 9, 10, 11, 12 and 13 (1946).

F. R. Palmer, "Tool Steel Simplified", Carpenter Steel Co. (1937).

Peter Payson, "The Annealing of Steel", Crucible Steel Co. of America (1943).

John McIntyre, "Experiments on Sodium Cyaniding of High Speed Steel Prior to Hardening", Trans. Am. Soc. Metals.

D. P. Antia, S. G. Fletcher and Morris Cohen, "Structural Changes During the Tempering of High Carbon Steel", Trans. Am. Soc. Metals.

S. G. Fletcher and Morris Cohen, "The Dimensional Stability of Steel. Part 1—Subatmospheric Transformation of Retained Austenite", Trans. Am. Soc. Metals.

Morris Cohen and P. K. Koh, "The Tempering of High Speed Steel", Trans. Am. Soc. Metals.

Paul Gordon, Morris Cohen and R. S. Rose, "The Effect of Quenching-Bath Temperature on the Tempering of High Speed Steel", Trans. Am. Soc. Metals.

CONTENTS NOTED

A monthly department dedicated as a forum for the interchange of ideas between readers and editors. All readers are urged to take advantage of this space and participate in the discussions presented.

Telnic Bronze

To the Editor:

We have noticed certain errors in the discussion of tellurium copper in the article on Engineering Bronzes which appeared in the April issue of MATERIALS & METHODS (Materials & Methods Manual No. 14). It is apparent to us that the material given in the third and fourth paragraphs under "Tellurium Copper," page 1037, actually apply to another alloy, "Telnic" Bronze, which is an age-hardenable alloy of attractively high strength and machinability.

I suggest that the following information be inserted under the suggested heading and the paragraphs in question be deleted:

Nickel - Phosphorus - Tellurium Bronze

"Telnic" bronze, or nickel-phosphorus-tellurium bronze, contains nominally 97.68% copper, 1.1% nickel, 0.22% phosphorus, 0.5% tellurium and 0.5% zinc. This is a relatively free-machining modification of the nickel-phosphorus bronze and embodies the distinctive characteristics of good machinability, hot and cold workability, conductivity, high strength and age-hardenability. Its machinability rating is approximately 80% of that of free-cutting brass. Temperature range for forging is approximately 1400 to 1600 F.

Heat treatment consists of a solution treatment, which leaves the parts soft and suitable for cold working, and an aging treatment. For the solution treatment the work is quenched or cooled rapidly from 1400 to 1500 F. When a cold-working operation follows, the aging treatment consists of heat for 1 to 3 hr. at 775 F. When no cold work has been done, the temperature for the aging treatment is increased to 850 F.

The alloy is being used for bolts, nuts, screws, high-strength screw machine parts, forgings, etc.

Also, on page 1037 the table heading should be changed from "Tellurium Copper" to "Telnic Bronze," as the properties listed are for Telnic bronze.

H. L. Burghoff,
Research Metallurgist

Chase Brass & Copper Co.,
Waterbury, Conn.

Unfortunately, Mr. Burghoff's letter dealing with this misidentification arrived too late to make the suggested changes in reprints of Manual No. 14. We suggest that readers make the corrections indicated in their reference copies. If there should be a further printing of reprints, the suggested changes will be made.—The Editors.

Automatic Stirring of Salt Baths

To the Editor:

I have read with interest in your magazine the article "Sodium Hydride Descaling," and find it quite informative.

In reference to the statement "electromagnetic force which provides automatic stirring action throughout the entire bath," I would like to ascertain how the author arrived at this conclusion. It is common knowledge and from the writer's personal observations that the salt in baths heated from the outside by electric power will seethe or "automatically stir." In fact, this inherent phenomenon is the reason why the temperature regulation in salt baths is so close. The same seething condition, slightly exaggerated, occurs when resistance wound electric immersion units are used for heating the bath. So far as I know it does not depend upon magnetic action.

I am therefore interested in hearing how the author arrived at this conclusion. It is possible that others having experience with gas or oil fuel salt pots might have some observations to relate.

Harold E. Trent

Harold E. Trent Co.,
Philadelphia, Pa.

According to both the author of "Sodium Hydride Descaling," Mr. E. L. Cady, and an official of Ajax Electric Co., Inc., makers of the salt furnaces used, the circulation in the bath is electromagnetic rather than thermal. This fact is apparent in the fact that the flow of molten salt in contact with the immersed electrodes is downward rather than upward. The liquid salt is drawn into the gap between the closely spaced electrodes and is forced downward between them by the same phenomenon that causes the armature of an electric motor to rotate in its magnetic field. In externally heated baths stirring is dependent on a difference in temperature between two or more points in the bath. A bath circulation dependent on such temperature differ-

(Continued on page 139)

THERE'S A NEW PLUS VALUE IN TUBING

N-A-X HIGH-TENSILE steel has now been "put to work" in the tubing field.

The high inherent properties of this low-alloy steel open the door to better values in tubular parts and products. Its strength gives designers the choice of *reducing mass* or *increasing durability* in such diversified applications as bicycle frames, porch furniture, auto seat frames, bus stanchions, garden implements and scores of others. Resistance to impact and fatigue is exceptionally high, corrosion-resistance very good.

N-A-X HIGH-TENSILE is easy to form and to weld by standard commercial processes. Weldments are unusually strong and tough, with good ductility retained in the heat-affected zones.

Electric-welded N-A-X HIGH-TENSILE tubing is now available through various tubing manufacturers.

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CONTENTS NOTED

Continued from page 137

ences is undesirable in a bath containing sodium hydride because that material is extremely sensitive to temperature and its rate of decomposition goes up rapidly if heated above 720 F.—The Editors.

Galvanic Corrosion Between Aluminum and Iron

To the Editor:

In the March 1946 issue of MATERIALS & METHODS you published a letter requesting information concerning galvanic corrosion that might occur between aluminum and iron. The letter specifically sought information in joining iron tubing to aluminum tubing and asked if there would be galvanic corrosion between the iron screws and the aluminum. Your published reply said that although it was unsafe to make predictions about corrosion behavior in absence of complete information, you believed that there would be less severe attack if the iron were replaced with copper. You also stated that 2S would be attacked faster than aluminum alloys such as 17S or 14S.

The Aluminum Research Laboratories have exposed many specimens both to specific environments in the laboratory and to natural exposure conditions such as are encountered in the atmosphere and in various natural waters. In solutions such as sea water containing chlorides, aluminum alloys, such as 2S, 3S, 4S, 52S, 53S, or 61S, will suffer some galvanic corrosion when in contact with iron, but this will be less severe than when in contact with copper.

When exposed to marine atmospheres, the amount of galvanic corrosion of the aluminum is much less than when immersed in sea water. In natural waters which are very low in chlorides and which are not pronouncedly alkaline (waters having a pH of 3 to 8) the galvanic corrosion of the above aluminum alloys has not been found to be very great, and even in some cases the potential relationships are such that the iron will have some tendency to protect the above aluminum alloys.

In all such exposures as described above, copper and copper-base alloys, such as brasses and bronzes, will cause considerably more galvanic corrosion of aluminum alloys than will iron or low carbon steel. The worst conditions are where appreciable amounts of chlorides are present.

For the application in question we would suggest the use of 18:8 stainless steel screws. If they are not available, galvanized steel screws would probably function satisfactorily. If the zinc coating is of sufficient thickness, the zinc will electrochemically protect both the aluminum and the steel. Of course, after the zinc coating has been removed by galvanic attack, the screw will function as an iron screw, but this is preferred to the use of screws of copper or copper-base alloys.

The general resistance to corrosion of duralumin type alloys, such as 17S or 14S, is not as good as that of the above mentioned aluminum alloys. However, because the solution potential of the duralumin type alloys is dependent on heat treatment, the galvanic corrosion between them and iron will be changed by the temper of the alloy, but again the galvanic corrosion will be less than between these aluminum alloys and copper.

R. H. Brown,
Chief, Chemical Metallurgy Div.,
Aluminum Research Laboratories

Aluminum Co. of America,
New Kensington, Pa.

Our thanks to Mr. Brown for his detailed information on the corrosion behavior of aluminum alloys. Fortunately, we did not advise Mr. Harold, writer of the subject letter, incorrectly, although the answer as published in the March "Contents Noted" would indicate that we did. We apologize to our readers who may have been misinformed by the published reply to Mr. Harold.—The Editors.

Manual on Availability of Wrought Forms

To the Editor:

I believe that you could prepare a valuable and widely useful manual on available forms and relative availability of various standard wrought materials. What I have in mind is that the specifying man all too often has no information to guide him in picking materials in various forms on a basis of probable availability in the required form. When I say availability, I mean, of course, normal rather than emergency conditions.

A good example of the utility of such a manual would be to suggest whether AISI 310 is more available than 316 stainless steel and whether either is available in the form of tubing. Another example would show that AISI 8630 is fairly readily available in tubing form. Such tables as those given for commodities in the Alcoa Handbook do not indicate relative availability but only standard forms. In many instances the specifier would be glad to adapt his material to conditions of availability if he had some ready reference as to probable availability.

H. C. Alois

Hoboken, N. J.

This manual suggestion sounds interesting to us. If enough readers indicate a desire for such a compilation, we will consider undertaking the project for early publication.—The Editors.

ENGINEERING DATA ON PLASTICS

4. PREHEATING

Preheating of phenolic materials prior to molding is recommended for economical production and for superior properties in the finished piece.

Advantages of Preheating

Preheating softens the resin, and this makes practical the use of lower pressures during molding, lessens the time required to close the mold, eliminates some or most of the volatiles (resulting in superior electrical properties), shortens curing time because the material is hot and in a semi-plastic stage prior to loading into the mold, and lessens wear on the mold surface.

Methods of Preheating

The following methods of preheating are the most frequently used: (1) surface contact on a steam platen, (2) closed steam or electric ovens, (3) cylindrical rotating container ovens, (4) infra-red lamps, (5) super-heated vapors, (6) turbulence of hot air, and (7) high frequency.

The best results are obtained by the methods which will allow the heat to penetrate through the material at a uniform rate of temperature or, if possible, slightly higher in the center of the material. The usual preheating temperature range in production molding is from 200° to 280° F. However, in some cases, particularly on fast operating presses in both compression and transfer molding, it is desirable to closely approach the mold temperature.

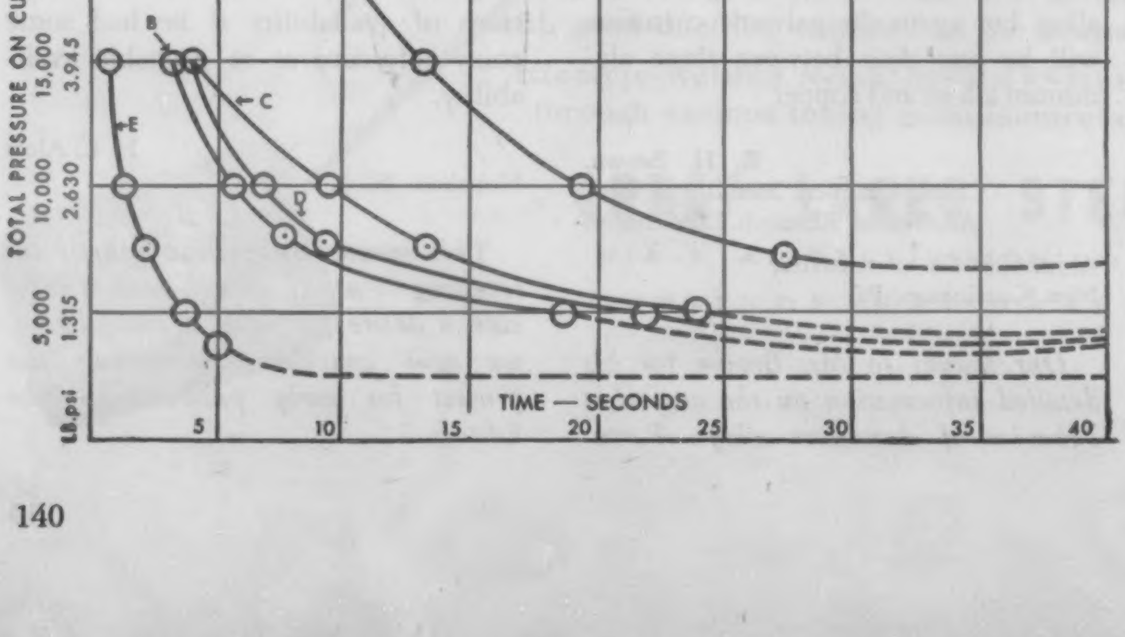
Preforms Recommended

Preforms are preferable for preheating by most of the methods. However, loose powder can be preheated provided it is agitated by rotation or other means, particularly when the lamp or oven method is used.

Preheating a quantity of loose powder by means of infra-red lamps or drawer type ovens can cause serious difficulties, especially when a hopper method of feeding is used. When the hopper is filled the preheated material retains the heat for some time, causing further resin reaction which advances some of the material to a semi- or even to a completely cured stage. Molded parts produced from this material will show surface blisters. Actually, these are not the usual blisters caused by undercure but are hard spots produced by the cured granules or particles. Longer cure will in many cases reduce or even eliminate these spots because the surrounding material has been cured to a greater rigidity. Non-uniformly preheated preforms will also cause surface-blistered parts, especially with slow-loading methods or a slow-closing press.

Flash Mold Difficulties

When thoroughly preheated pills are used in a flash mold, especially on a shallow draw part, difficulties with unfilled parts may be encountered because of insufficient back pressure within the cavity. It is often necessary to overload the charge considerably to



allow for flashing or to control the press-closing speed closely so that the material can be retained in the cavity. Best results are obtained in semi-positive or positive molds.

Curing Time

Production advantages with preheated material depend entirely on the method and degree of preheating. In many instances the curing time is obtained after the mold has been closed. This procedure is incorrect. The time of cure should include the closing time of the mold, for very often the difference in the speed of closing can be costly.

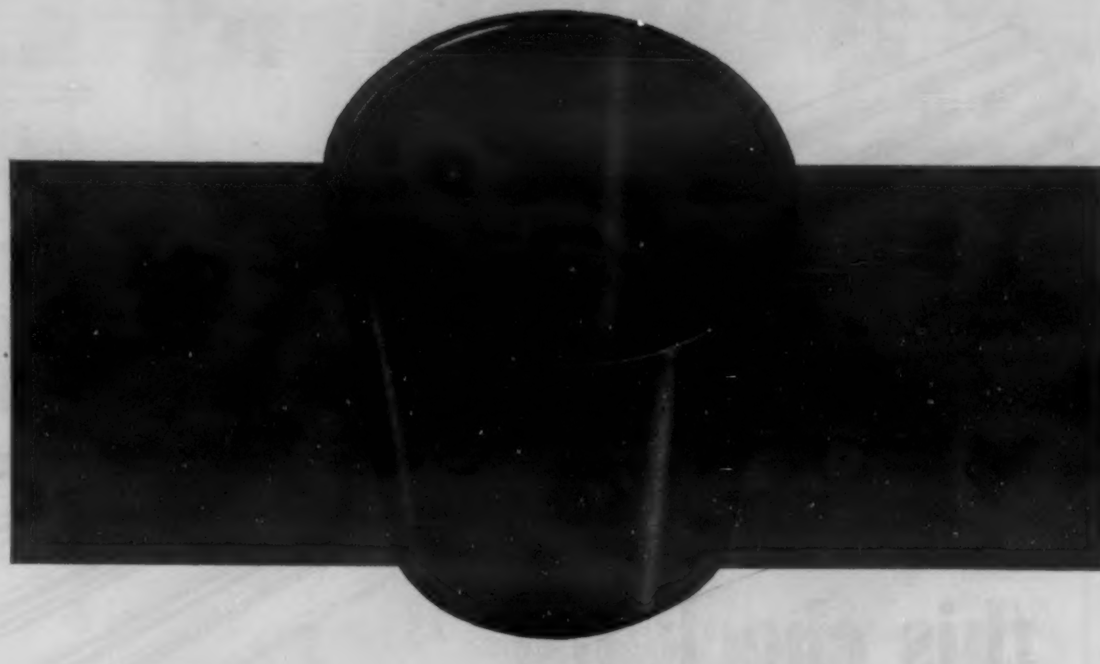
The inserted curve chart illustrates the difference between closing time and pressure in some of the methods of preheating. For example, Test A...Preformed general-purpose material in "as received" condition molded in the mobility test cup (Fig. 1) at 2630 psi on the molded projected area required 19.8 seconds to close and 70 seconds to cure. Therefore, the complete cycle of closing and curing was 89.8 seconds.

For Test B the preforms were preheated in an electric oven at 230° F. for 15 minutes. The closing time was 5.5 seconds, curing time was 50 seconds . . . the complete cycle 55.5 seconds.

For Test C the preforms were preheated on one side by means of infrared lamp. The closing time was 9.7 seconds, curing time was 60 seconds . . . the complete cycle 69.7 seconds.

For Test D the preforms were preheated on both sides by means of double infra-red lamps. The closing time was 6.5 seconds, curing time was 55 seconds ... the complete cycle 61.5 seconds.

For Test E the preforms were preheated by high frequency for 30 seconds at a temperature of 240° F. The closing time was one second and curing time 38 seconds. The complete cycle was 39 seconds. Conducting Test E at 1315 psi, it was possible to obtain the same complete cycle as on 2630 psi. The closing time, however, was increased to 3.6 seconds.



Even the slightest degree of preheating will speed up the molding cycle as illustrated in Tests A and C. The most economical cycle, however, was obtained in Test E.

Improving Electrical Properties

To obtain the best possible electrical properties, the methods which will eliminate moisture or other volatiles are recommended rather than methods which might possibly increase moisture content.

Physical and electrical properties were improved considerably by preheating general-purpose material. The molding and preheating procedures on the test specimens were as follows:

IMPACT BARS . . . Molded at 150° C. at 5000 psi. Bars pulled hot.

Regular:	Cured 10 minutes
1/2 hr. oven preheat at 93° C.:	Cured 10 minutes
High-frequency preheated 45 seconds:	Cured 5 minutes
Infra-red preheated 4-1/2 minutes:	Cured 10 minutes

TENSILE BARS . . . Molded at 160° C. at 6000 psi. Bars pulled hot. 1/4" dogbone type.

Regular:	Cured 10 minutes
1/2 hr. oven preheat at 93° C.:	Cured 10 minutes
High-frequency preheated 60 seconds:	Cured 5 minutes
Infra-red preheated 4 minutes:	Cured 8 minutes

DISCS . . . Molded at 150° C. at 6000 psi.

Regular:	Cured 15 min.	Cooled 15 min.
1/2 hr. oven preheat at 93° C.:	Cured 10 min.	Cooled 10 min.
High-frequency preheated 45 seconds:	Cured 5 min.	Cooled 10 min.
Infra-red preheated 4 minutes:	Cured 10 min.	Cooled 10 min.

	Regular	1/2 Hour Oven Preheat	High-Frequency Preheat	Infra-red Preheat	
Volume resistance	160	583	745	372	megohms
Insul. resistance	158.5	560	635	368	megohms
Vol. resistivity	1.07×10^{10}	3.95×10^{10}	4.94×10^{10}	2.51×10^{10}	ohms cm.
Diel. strength	398	430	433	437	V/M
Power factor	.043	.036	.036	.040	1000 KC
Diel. constant	5.6	5.3	5.2	5.4	1000 KC
Tensile	6872	6558	8176	6326	psi
Impact	.288	.308	.294	.320	per inch of notch
Flexural	11980	11850	11230	12370	psi

Impact and flexural were side breaks.
All specimens were conditioned 96 hours at 25° C. and 50% R. H.

DUREZ PLASTICS & CHEMICALS, INC., 97 WALCK ROAD, NORTH TONAWANDA, N. Y.

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MATERIALS & METHODS Engineering File Facts

NUMBER 117
July, 1946

MATERIALS: General

Shear Properties of Metals and Alloys

Part 3: Magnesium Alloys

Form	Commercial Specifications					Condition	Shear Strength, Psi.	Ratio of Shear to Tensile Strength
	Dow[1]	Mazlo[2]	ASTM	SAE	AMS[3]			
Permanent Mold Castings	G-AC	AM240-C	—	502	—	As cast	18,000	0.90
	G-HT	AM240-T4	—		—	Heat treated	20,000	0.57
	G-HTA	AM240-T6	—		—	Heat treated and aged	21,000	0.60
	—	AM240-T61	—		—	Heat treated and aged	22,000	0.61
	C-AC	AM260-C	—	503	—	As cast	18,000	0.78
	C-HT	AM260-T4	—		—	Heat treated	20,000	0.51
	C-HTA	AM260-T6	—		—	Heat treated and aged	22,000	0.58
Sand Castings	(B)	AM246-C	B80-44T, Alloy A12	—	—	As cast	17,000	0.89
	—	AM246-T6		—	—	Heat treated and aged	19,000	0.59
	C-AC	AM260-C	B80-44T, Alloy AZ92	500	—	As cast	18,000	0.75
	C-HT	AM260-T4		—	—	Heat treated	20,000	0.50
	C-HTA	AM260-T6		—	4434A	Heat treated and aged	—	TS[4] 40,000
	H-AC	AM265-C	B80-44T, Alloy AZ63	50	4420B	As cast	18,000	0.67
	H-HT	AM265-T4		—	4422B	Heat treated	19,000	0.47
	H-HTA	AM265-T6		—	4424B	Heat treated and aged	20,000	0.56
	M-AC	AM403-C	B80-44T, Alloy M1	—	—	As cast	11,000	0.79
	G-AC		B80-44T, Alloy A10	—	—	As cast	17,000	0.77
	G-HT	—		—	—	Heat treated	19,000	0.58
	G-HTA	—		—	—	Heat treated and aged	21,000	0.62
Die Castings	—	AM230-C	B94-44T, Alloy AS100	—	—	As cast	—	TS[4] 32,000
	R	AM263-C	B94-44T, Alloy AZ90	501	4490A	As cast	20,000	0.60
	—		B94-44T, Alloy AZ90X	—	—	As cast	—	TS[4] 32,000
Forgings	J-1	AM-C57S	B91-44T, Alloy AZ61X	531	4350A	Press forged	21,000	0.50
	O-1	AM-C58S	B91-44T, Alloy AZ80X	532	4360	Press forged	22,000	0.49
	—	AM65S	B91-44T, Alloy AT35	53	—	Hammer forged	16,000	0.42
	—	AM-C74S	B91-44T, Alloy AZ33X	—	—	Press forged	20,000	0.49
	—	AM-C74S-T5	—	—	—	Press forged and aged	21,000	0.50
	M	—	—	533	—	Forged[5]	—	TS[4] 36,000

[1]*Dowmetal alloy numbers, Dow Chemical Co.:*

Meaning of the Dow suffixes:

Suffix	Meaning
AC	As cast
ACS	As cast and stabilized
HT	Heat treated
HTA	Heat treated and aged
HTS	Heat treated and stabilized
a	Annealed
h	Hard rolled
r	As rolled

[2]*American Magnesium Corp. alloy numbers:*

Meaning of the Mazlo suffixes:

Suffix	Meaning
C	As cast
T4	Heat treated
T5	Aged
T6	Heat treated and aged
T61	Heat treated and aged
O	Annealed
H	Hard rolled
R	Hot rolled

[3]*Aeronautical Material Specifications of the Society of Automotive Engineers, Inc.*

[4]*Where the shear strength of common alloys is not available, the tensile strength (in psi.) is given*

[5]*Data for both press and hammer forgings*

(Continued on page 145)


Diesel Engine BABBITT
NATIONAL BEARING DIVISION
AMERICAN Brake Shoe COMPANY
ST. LOUIS, MO.
NBM

NUMBER 117 (Continued)

SHEAR PROPERTIES OF METALS AND ALLOYS, Part 3

Form	Commercial Specifications					Condition	Shear Strength, Psi.	Ratio of Shear to Tensile Strength
	Dow[1]	Mazlo[2]	ASTM	SAE	AMS[3]			
Sheet and Plate	Ma	AM3S-O	B90-44T, Alloy M1	51	4370	Annealed	19,000	0.59
	Mh	AM3S-H			—	Hard rolled[4]	20,000	0.56
	FS-1a	AM-C52S-O	B90-44T, Alloy AZ31X	510	—	Annealed	21,000	0.55
	FS-1h	AM-C52S-H			—	Hard rolled[4]	21,000	0.46
	J-1a	AM-C57S-O	B90-44T, Alloy AZ61X	511	4380	Annealed	20,000	0.48
	J-1h	AM-C57S-H			4381	Hard rolled[4]	22,000	0.44
Extruded Rod, Bar and Shapes	M	AM3S	B107-44T, Alloy M1	522	—	As extruded	16,000	0.43
	—	AM52S	B107-44T, Alloy AZ31	—	—	As extruded	19,000	0.48
	FS-1	AM-C52S	B107-44T, Alloy AZ31X	52	—	As extruded	19,000	0.48
	—	AM57S	B107-44T, Alloy AZ61	520	—	As extruded	20,500	0.47
	J-1	AM-C57S	B107-44T, Alloy AZ61X	—	4350A	As extruded	20,500	0.47
	—	AM58S	B107-44T, Alloy AZ80	—	—	As extruded	21,500	0.46
	O-1	AM-C58S	B107-44T, Alloy AZ80X	—	—	As extruded	21,500	0.46
	—	AM59S	—	—	—	As extruded	23,000	0.47
	—	AM-C74S	B107-44T, Alloy AZ33X	521	—	As extruded	20,000	0.48

[1]*Dowmetal alloy numbers, Dow Chemical Co.:*

Meaning of the Dow suffixes:

Suffix	Meaning
AC	As cast
ACS	As cast and stabilized
HT	Heat treated
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HTS	Heat treated and stabilized
a	Annealed
h	Hard rolled
r	As rolled

[2]*American Magnesium Corp. alloy numbers:*

Meaning of the Mazlo suffixes:

Suffix	Meaning
C	As cast
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T6	Heat treated and aged
T61	Heat treated and aged
O	Annealed
H	Hard rolled
R	Hot rolled

[3]*Aeronautical Material Specifications of the Society of Automotive Engineers, Inc.*

[4]*American Magnesium Corp. supplies sheet that is heavier than 10 ga. (0.102 in.) and plate in the "As-Hot-Rolled" (R) condition instead of in the "Hard-Rolled" (H) condition; mechanical properties of hot rolled material are intermediate between those of hard rolled and annealed sheet.*

Note: Data obtained from publications of the following organizations:
ASTM (Standards, 1944, Part I)
American Magnesium Corp.
Dow Chemical Co.

Compiled by Robert S. Burpo, Jr., Associate Editor

engineering

SHOP NOTES

Tapping Quadruple Threads

by Otto Starke,
Westinghouse Electric Corp.

A new method of tapping a special bronze nut has tripled production and greatly decreased the number of defective parts. The unit has a ¾-in. I.D., a 1.120-in. O.D., and is 1-⅞ in. long; it has a quadruple 29-deg. Acme thread, a 1-in. lead, and a ¼-in. pitch.

When the nut was first put into production an attempt was made to chase the threads on a lathe with a single point cutting tool. Because of the percentage of scrap, a series of five taps were developed to cut the thread.

As by the old method, the steps in making the nuts are cut off, drill, face and thread. Instead of chasing the threads in a lathe they are now tapped on a Universal turret lathe in five steps. To facilitate tapping, the threads on both the nut and screw are tapped to ¾ of the full depth. The operator runs the taps into the nut and, as he removes each one from the chuck, he washes it in kerosene oil to remove the chips. There are notches on the shanks of the taps to aid the operator in using them in the proper sequence.

One step in the tapping sequence; the shank of each tap is notched to aid the operator in selecting the correct tool in the series.

This same method has also been applied to a ⅝-½ double thread Monel nut that could not be chased successfully with a single point tool.

Repairing Broken Punch Press Ram

by Peyton T. Koch,
International Steel Co.

Some time ago a ram on one of our punch presses pulled in two on the return stroke while trying to pull the punch out of the work against the stripper plate. Since we were unable to pick up a ram to fit this machine, we decided to make one from a steel plate.

This was the procedure under which the steel ram was made. We first made a blueprint of the broken ram. Next a piece of steel was burned to within a half-inch of the size needed, then completely machined to the right size. To keep this steel ram from galling in the cast steel ways of the punch press it was then sprayed with bronze wire (Sprabronze M).

After preparing one side of the ram at a time, we sprayed it, put it back on the shaper, and prepared the next side. The reason we sprayed only one side at a time was that we were afraid of grease and dirt getting on the other three sides in handling from the shaper to the spray booths. Now this operation had to be repeated three times. After having all three sides sprayed we machined back to original size. About 50 lb. of metal were used to spray about 500 sq. in.

Made in approximately 50 hr., this ram will be in good shape a long time after the punch press itself is worn out. This steel ram cost the company around $225.00. For a cast iron ram, we would first have had to make a pattern, then have it machined. Pattern, casting and machining would have cost us about $400.00 and delayed us about four more days.

—Courtesy of "Metco News"

When wearers of bi-focals use the standard welding hood with the window directly before their eyes they cannot see their work through the "near" field of view, because it falls below the window. Mustoche and Schnoor recommend the placing of lenses into the hoods which would convert the far-view lenses in the eye glasses to the proper near view. These correcting lenses are mounted in a plastic plate inserted in the glass window of the hood.

—Permanente Found. Med. Bull.
Industrial Hygiene Digest

Single-Exposure Technic for Radiographic Inspection of Bronze Castings

by Stanley A. Brosky, Pittsburgh Testing Laboratory

Seeking to eliminate defective castings of bronze or brass before machining, the Pittsburgh Testing Laboratory devised a method of X-ray inspection, which, while keeping sorting costs low, has proved more than 90% effective.

One of the laboratory's clients had complained that the percentage of castings scrapped after machining generally ran from 50 to 75%. Investigation of the faults leading to rejection showed that castings would not "clean up" during machining, that they leaked during air pressure tests through what visually appeared to be sound metal, and that surface defects extended deeper and were more serious than visual inspection usually indicated. In addition, castings were found to leak in a given area characteristic of the specific type of casting.

Since many of these castings did not justify the expense of multiple radiographic inspection, a single-exposure technic was developed. The results of this technic proved conclusively that in most instances a single radiograph, of an area known to be questionable, can supply all the information necessary to separate acceptable brass or bronze castings from those which are unacceptable. The results further proved it is possible to tell by radiography whether or not a casting will leak under air pressure.

By correlating the study of radiographs with the results disclosed in machining, it was discovered that some castings leaked despite the absence of any large defects on the radiograph. Here radiographic interpretation of brass or bronze departed in one important respect from customary procedure: obvious defects, including porosity, blow holes and shrinkage areas, were more or less ignored. What was studied was the condition of the metal between such defects.

If the radiograph showed a mottled, hazy background, interspersed with dark pinpoint or fine sand-like inclusions, experience proved the casting would leak when subjected to air pressures of 10 to 250 psi. Such castings were unacceptable. On the other hand, castings whose radiographs showed a uniform fine grain structure often were acceptable despite gas pockets and similar defects, depending on the nature, size, and location of irregularities.

Using this method, bronze and brass castings with wall thicknesses up to 1¾ in. have been examined successfully. While four of the first 100 castings examined were later rejected after machining, results improved as experience in the use of the technic was gained. Since December 1945 not one of approximately 4000 castings, judged acceptable through radiography, failed to machine up perfectly.

While the single-exposure technic does not supply as much information as a complete radiographic examination, it does supply in many cases sufficient information to judge the castings' acceptability, and at a cost which makes it possible to inspect items of value insufficient to warrant a 100% examination. However, the success of the method is dependent on interpretation.

Without a solid groundwork in radiography, and without careful correlation of over-all radiographs with results, it would be impossible to develop such a single-exposure technic. Room remains, nonetheless, for technical improvements; a more fine-grained film than the fast type used in these tests might permit more critical inspection wherever necessary.

Preventing Induction Furnace Failures

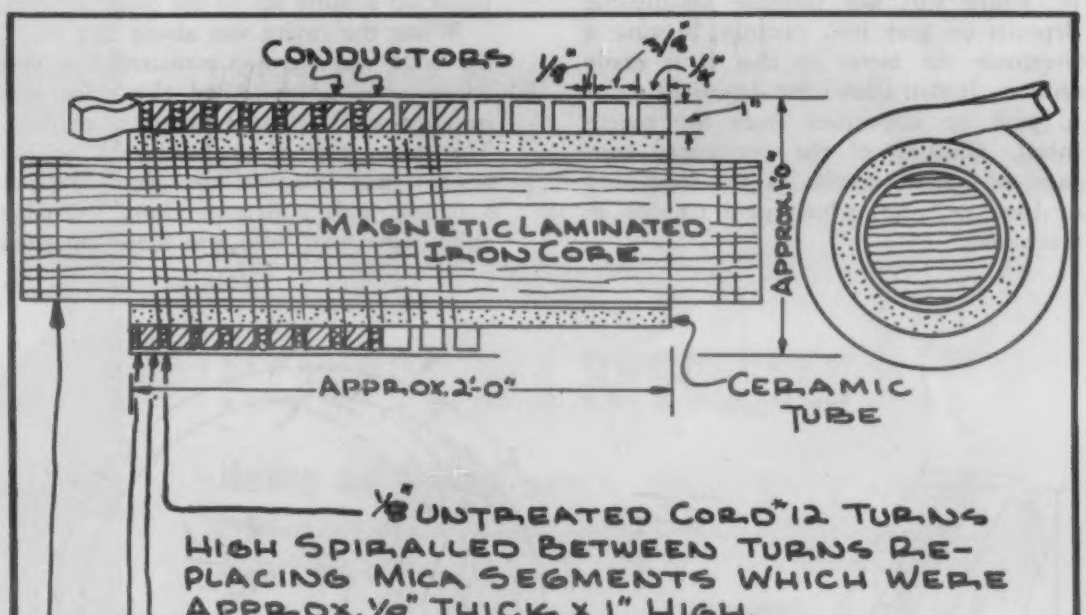
by John L. Talbert, U. S. Naval Gun Factory

On the average of once a month, a primary coil would burn out in one of the four induction furnaces used for melting copper for shell cases. Mica flakes used to insulate the ⅛-in. space between conductors would powder out under vibration and other service conditions. Spalling-off of the ceramic mud over the coil assembly would result in loss of the mica flakes.

This condition created a short between the conductors and took the furnace out of production. Because the furnace cooled immediately, the ceramic lining in the furnace proper was damaged, and it was necessary to reline the entire furnace. Furnace relining cost $3500 per yr., aside from the production loss incurred. Experimental use of several types of inorganic tapes and cords in an effort to prevent coil failure proved unsatisfactory under service conditions of 1500 F, attained in the primary coils.

Fiberglas cord was tried and it proved a successful solution to the problem. The Fiberglas cord was placed in the spacing between conductors. Twelve turns of the cord were applied between the conductors. Sodium silicate, which is resistant to high temperatures, was applied over the cord and allowed to dry. The assembly was sheathed with ceramic mud.

Coils insulated in this manner have been in operation as long as 18 months without failure. The repaired coils have held up under a 75% overload furnace schedule. Recently the furnaces were converted from 220 v. to 440 v. operations, and the repaired coils were in excellent shape after months of continuous use.



Cross-sectional view of primary coil of induction furnace at U. S. Naval Gun Factory, Washington, D. C.

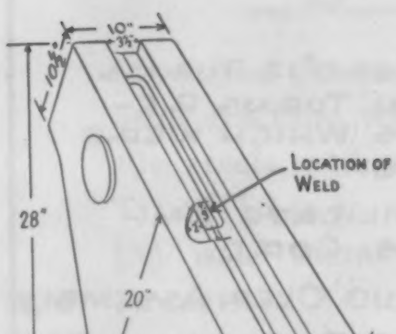
Tips for Arc Welding Gray Iron Castings

by C. E. Phillips,
C. E. Phillips & Co.

Although the variety of practical and economical applications of the metallic arc welding process to the salvage of defective, worn or broken gray iron castings is very large, this does not mean that every new job presents an entirely different problem. Most jobs can be quickly identified as belonging to a certain group, and the correct procedures for all jobs in any group will differ only in certain details.

One general classification includes castings that require building up with additional metal in certain areas. One of the chief difficulties encountered in all built-up operations is the development of hard spots (hardness in the deposited metal in the line of fusion and in the heat affected zone of the parent metal). Many so-called failures have been reported, even when the correct electrode material has been used; investigation has usually disclosed that these failures were caused by lack of any effort to make the deposit in such a manner as to preserve the full machinability of the casting.

The experienced arc welder working on ordinary steel usually "digs in" or tries to get good penetration. At the same time, he uses as large an electrode as the work will stand, in order to reduce welding time. Such arc welding procedure will not produce machinable deposits on gray iron castings, because it overheats the metal so that it is easily chilled. It also allows the deposited metal to pick up impurities from the parent metal. Chilling of the overheated castings, of course, results in the formation of hard carbides, which give trouble in machining.



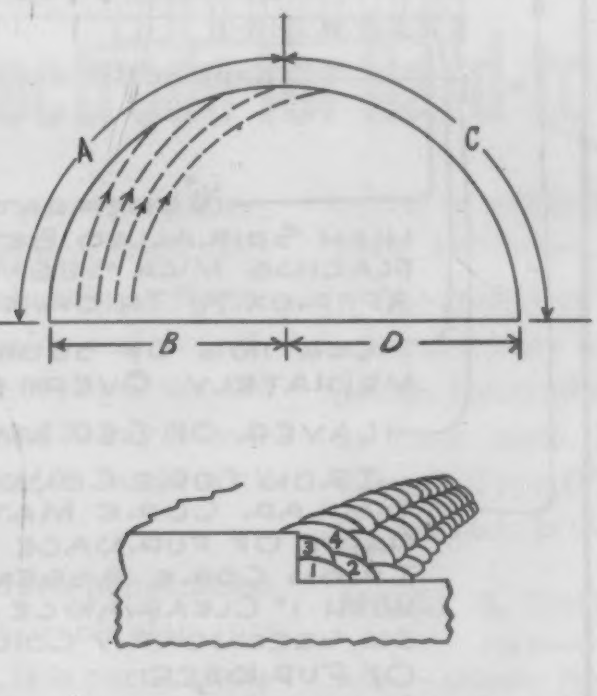
A good welding operator working with any good material can usually avoid porosity and checking in the deposit. Therefore, the thing he has to learn for the correct building up on cast iron is to avoid chilling, thus producing a fully machinable deposit, provided he uses electrode material making that result possible.

A specific case, in which it was necessary to watch the effect of the heat on the parent metal, is illustrated in the accompanying drawing. The casting weighed about 500 lb. A notch, approximately semi-circular, 3 in. long by 2 in. wide and ⅜-in. deep, had been milled alongside one of the machined ways. It was required to fill this notch, avoiding the development of any hard spots that would make subsequent machining difficult. There were two sharp corners to watch—one around the top of the notch, and another along the straight edge of the notch at the bottom.

With the work in the inclined position, welding was started in the lower corner and ⅛-in. from the edge. The first bead was carried only part way around the arc of the cavity. Three additional beads of about the same length were deposited. The approximate length of these deposits is indicated at A. The figure also shows how the beads overlapped.

In the case of each bead after the first, the arc was always held largely on the previous deposit; care was always taken to thoroughly clean away the slag from each bead before depositing the next one. By this time, a shoulder was formed on which additional beads were deposited to build up slightly above the original level.

When the cavity was about half filled, the edge was warmed sufficiently so that beads could be deposited along the area indicated at B, without danger of chilling. The upper half of the cavity (C in the figure) was filled in the same manner, finishing with a deposit along the edge at D. One final bead was then deposited



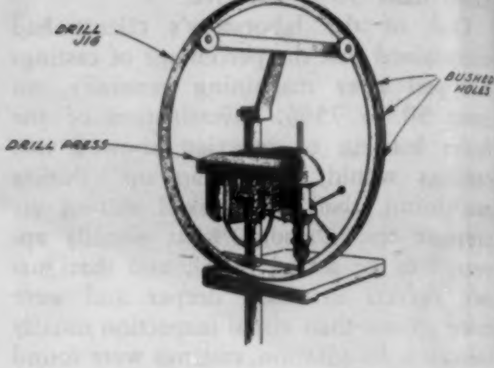
around the edge of the cavity to provide plenty of material for machining.

By following this procedure, it was possible to make this repair without preheating, which might have warped the casting. The job machined perfectly without encountering hard spots or porosities.

Drill Jig for a Drill Press

by Thomas A. Dickinson

It is extremely difficult to accomplish accurate work with an ordinary drill press when operations such as reaming and countersinking are necessary, because it is hard to align a reamer or similar tool with the center of a previously-drilled hole. Therefore, several West Coast manufacturers are now making use of drill



A sketch of one of the drill press jigs being used with ordinary drill presses for reaming and countersinking.

press jigs such as the one shown in the accompanying drawing.

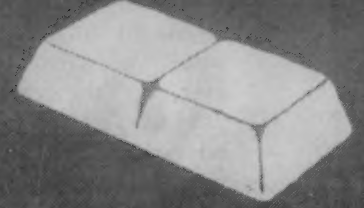
This drill jig comprises a circular band of steel in which bushed holes of various sizes are appropriately positioned. It is mounted on two rollers, which are supported at a suitable distance above the drill press by a T-shaped superstructure.

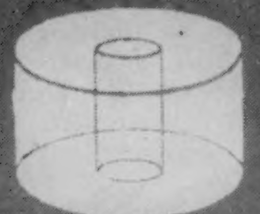
The roller mountings enable the drill press operator to rotate the jig until a bushing of the correct size is in line with the reamer or countersinking tool. Then it is a simple matter to align the hole in the work with the bushing, and to accomplish an accurate job of reaming or countersinking.

Letters or numbers on the jig enable the drill press operator to identify the bushed holes in a minimum amount of time.

The palletizing system of handling materials has accomplished what is said to be "the greatest mass movement of materials" in history, stated a prominent Navy man. Many palletized master loads have remained intact from factories to cars, to ships, thence to our Allies and overseas bases. It is efficient also within industrial plants. Thus, a maker of glass blocks palletizes. Each paperboard, steel-strapped carton holds three to four blocks. Master loads on pallets weigh 1 to 1½ tons. A chief advantage in factories is that it permits "air rights"—vertical space up to the ceiling. Skids are the conventional bases of pallets. They are easily handled and loaded with fork trucks.

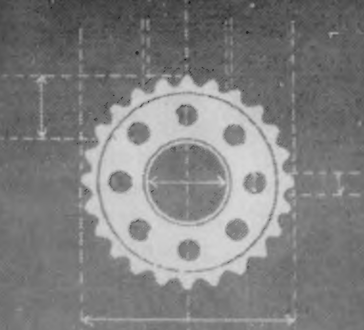
—C. B. Cook,
Elwell-Parker Electric Co.

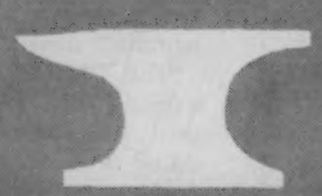




Edited by Robert S. Burpo, Jr.

Associate Editor,
Materials & Methods





MATERIALS & METHODS DIGEST

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Stress Corrosion Cracking of Mild Steel

Condensed from "Corrosion and Material Protection"

A general "precipitation" theory of stress corrosion has been developed which shows that its apparent cause is the precipitation of iron nitride, and that high local stresses induced by the presence of a crack accelerate the formation of a galvanic cell by accelerating precipitation; the crack then grows by the dissolution of newly formed anodic material.

The application of this theory to mild steel is based on the following previously known facts: (1) The effects of minor elements and of heat treatment on resistance to "boiler embrittlement", nitrate attack and age hardening are similar in kind and degrees; (2) corrosion cracking and age hardening are caused in general by the precipitation of some material, probably iron nitride in the case of steel; (3) precipitation is accelerated by straining; and (4) high stresses are produced locally by the presence of cracks.

Non-aging steels have so been developed of the following compositions:

Designation of Steel	107	108	109	110	111	112
Carbon	0.003	0.320	0.315	0.059	0.077	0.059
Manganese	0.370	1.48	1.68	0.38	0.31	.38
Phosphorus	0.008	0.020	0.020	0.01	0.01	0.008
Silicon	0.001	0.260	0.280	0.006	0.06	0.08
Sulphur	0.021	0.040	0.035	0.019	0.013	0.005
Nitrogen	0.0036	—	—	0.0055	0.0035	0.0015
Aluminum	0.011	0.044	0.098	0.060	0.040	0.090
Titanium	—	—	—	0.010	0.35	0.44
Copper	—	—	—	0.09	0.07	0.05

The following facts were not explained by any one of the previous theories: (1) Stress corrosion cracks are mostly intercrystalline, slightly transgranular, and slightly branched; (2) elements in the steel affect resistance to cracking; and (3) cracking is inhibited by (a) cathodic protection, (b) compressive stresses, and (c) removal of nitrogen.

The stress acceleration of the precipitation of iron nitride and the formation of ferrous hydroxide from it by corrosion are both thermo-dynamically feasible. A "free nitrogen factor" has been developed which measures the amount of nitrogen available to form iron nitride.

Significant linear correlations have been shown to exist between any two of the following three: (a) extent of aging, (b) rate of cracking, and (c) "free nitrogen factor." It could be established that (a) the removal of nitrogen renders steel resistant to stress corrosion, and (b) the proper reintroduction of nitrogen renders steel susceptible to stress corrosion again. It was found that steel may be protected from stress corrosion by (1) shot peening, (2) nitriding, (3) cathodic protection, and (4) wet hydrogen treatment. Nitrogen can be effectively eliminated by the addition of either aluminum or titanium.

All investigations show clearly that the mechanism of stress corrosion is electrochemical in nature. Cathodic protection increases the life of even cracked specimens. A great number of tables and diagrams illustrate the various factors and test results.

—James T. Waber, Hugh J. McDonald & Bruce Longtin. *Corrosion & Material Protection*, Vol. 2, Nov. 1945, pp. 13-16; Dec. 1945, pp. 13-16; Vol. 3, Jan. 1946, pp. 13-18; Feb. 1946, pp. 13-20; Mar. 1946, pp. 13-23; Apr. 1946, pp. 13-18.

Reclaimed Aluminum

Condensed from "Metallurgia"

"Secondary metal" is a term applied almost entirely to aluminum. No distinction is made in the case of copper and iron alloys between products manufactured from reclaimed material and those produced wholly or partly from virgin stock. However, in the early 1930's, many small producers of secondary aluminum exercised no care in the production of ingots, with the result that the product marketed was unsuitable for most purposes.

The few producers of scientifically controlled secondary aluminum were faced with the difficult task of overcoming the damaging reputation caused by the smaller producers. The outbreak of the war in 1939 greatly increased the demands on producers of aluminum. Secondary aluminum was used more extensively, and the aid of the Ministry of Aircraft Production in establishing standards for quality control was instrumental in the production of secondary aluminum of aircraft quality.

Secondary aluminum will undoubtedly find widespread postwar uses in both the United Kingdom and the United States. Expected annual consumption in the United States is expected to be around 300,000 tons.

Substitution of aluminum for unstressed brass components in various structures will help expand the market, and the normal expansion of aluminum into various fields will result in increasingly widespread use of secondary aluminum.

—F. H. Smith. *Metallurgia*, Vol. 33, Feb. 1946, pp. 207-209.

Silicon Impregnated Steels

Condensed from the "Iron Age"

High silicon iron alloys, while very resistant to corrosion, heat and wear, have been limited in use in that they can be made only in the cast form. They cannot be machined and are very brittle. If the silicon alloy were only in the outer layers of the article and were supported by a soft ductile core, the desirable properties of the silicon alloy would be obtained with the elimination of most of the undesirable ones.

The impregnation of metals with silicon was a laboratory rather than commercial proposition until recent years. A commercial process requires a cheap source of silicon which is afforded by silicon carbide, containing 70% silicon (the amorphous product contains 80% silicon). In the presence of chlorine at moderately high temperatures silicon is released for impregnation of metals.

The usual furnace for silicon impregnating is the rotating retort type, such as used for carburizing. Chlorine is introduced in each head through a stuffing box. For a retort an ordinary 10-in. extra heavy seamless low carbon steel pipe is used, 10 ft. long, with heated zone of 5 ft. Retorts have a life of 50 to 60 runs and fail from oxidation on the outside, the inside being protected by the chemical action.

In the furnace the retort revolves one revolution per 2 to 3 min. Insulating heads are made of molded ceramic material. A carbon tube is molded lengthwise through the head to conduct chlorine into the retort. Steel plate baffles confine the parts to be treated to the center heated zone.

In one of the more modern furnaces, 450 lb. of solid parts, such as shafts, may be

loaded into the furnace. About 45 lb. of silicon carbide is then shoveled upon the parts. The furnace is heated to 1825 to 1850 F; then chlorine gas is flowed in from one end at 2 lb. per hr. At the end of half the run the stream of chlorine is switched to the other end. Every 20 min. a rod is pushed into the outlet to free it of condensed ferric chloride.

A case of about 0.015 in. is produced in 30 min.; a 0.020-in. case is formed in 1 hr. and a 0.035 in. case in 2 hr. The latter is the normal commercial thickness. A 0.050-in. case may be produced in 3 hr. The work is not quenched or otherwise heat-treated since the silicon alloy case cannot be changed by any known heat treatment. The retort is then charged for a second run. The parts come out fairly clean and may be brushed if necessary. Any ferric chloride may be removed by steaming or boiling in water.

About 200,000 water pump shafts for large industrial internal combustion motors have been silicon carbide treated, with some in service for 10 yr. Such shafts replace those of stainless or nitrided steel. Another use is exhaust manifolds for large marine engines in salt water. Treated chains for marine and industrial use have been successful. Silicon treated parts resist scaling in air up to 1400 F, and they are not effected by many corrosive fluids, though violent corrosive agents, such as boiling acids, attack their surfaces.

—Harry K. Ihrig. *Iron Age*, Vol. 157, Apr. 4, 1946, pp. 73-78.

Non-Elastic Deformation of Metals

Condensed from "Journal of Applied Physics"

The stress strain relation of an ideal metal should be divided sharply into an elastic and a plastic region, but no real metal possesses an ideally elastic region. Anelasticity is a property of solids in virtue of which there is not a unique relation between stress and strain. The origin of anelasticity may be associated with one of four factors: some sort of diffusion induced by applied stresses; isolated regions which behave in a viscous manner; dislocations or lattice distortions in the vicinity of a region of low shear resistance; and the formation of twins.

The viscous behavior of grain boundaries is of great practical importance in connection with creep and stress relaxation at elevated temperatures. The viscous flow in isolated regions may cause deviations of up to 100% from perfect elasticity.

There have been no recent tests on the relation between the rate of slip across grain boundaries and the stress and the causes of such slip. There is also need of new work on the at least temporary viscous behavior of slip bands.

Permanent deformation may occur by twinning or by slip. The mechanics of the initiation and growth of twin bands and of slip bands require additional exploration, particularly in respect to the drop in resistance to deformation which accompanies the initiation of slip bands.

The conditions for the initiation of twins appear to be very sensitive to structure. Unlike slip bands, twins may start in local regions of high stress concentration and

may propagate for a long distance through areas which were under no stress prior to deformation. Work should be done on the mechanics of the segregation of solute atoms in solid solution, such as carbon and nitrogen in iron, as the discontinuous yielding in mild steel and duraluminum may be related to supersaturation.

An exploration should be made of the conditions under which strain hardening is not removed by recovery or recrystallization and hence under which a mechanical equation of state exists; *i.e.* under which a relation exists between strain rate, strain, stress and temperature. Tests are also needed on the variation of the heat of activation for plastic strain rate upon stress and upon microstructure.

Anisotropy introduced by deformation has been insufficiently explained. A further understanding of plastic deformation must involve the evaluation of the modification of the mechanical equation of state by this anisotropy.

It is believed that adequate understanding of the mechanics of small plastic deformations will be obtained only through a study of the bases of the anelastic and Bauschinger effects, not through attempts to find empirical formal relations between the stress pattern and the elastic and plastic strains.

—C. Zener & J. H. Hollomon.
J. Applied Physics, Vol. 17, Feb. 1946, pp. 69-82.

Heat-Resisting Alloys

Condensed from "Foundry Trade Journal"

Because gasoline imports to Norway were cut off during the war, its use for private cars and buses was forbidden. Thus, gas producers using wood as fuel were installed. One of the most popular producers was based on the Imbert system, as applied by General Motors International, of Oslo. Combustion takes place on a hearth, the air entering through several small inlets into the main center, where descending wood is converted to carbon monoxide gas.

Temperatures as high as 2375 F (1300 C) were registered in the middle and the hearth was sometimes twisted and deformed. However, practically no scale was formed when the metal contained over 25% chromium.

Essential requirements for hearth materials were: They must withstand a temperature of 2000-3000 F (1100 to 1200 C) in an atmosphere of carbon monoxide gas in a bed of incandescent carbon; they must have ability to be welded to ordinary sheet iron without heat treatment; and must have fair machinability. At first, an alloy of 25% chromium and 20% nickel was used successfully, but soon had to be abandoned because of a shortage of nickel.

Tests were conducted to see whether a straight ferritic 25% chromium steel could be used. It was concluded that 2100 F (1150 C) is the limit to which 25% chromium steel can be heated in carbon monoxide gas. It was found that carbon up to 2.8% lowers the melting point of the 25-30% chromium steels.

High carbon also adversely affects the welding operation and makes the joint brittle. The same effects result from high silicon additions, though the alloy is more

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fluid when molten. After preliminary trials production was started and continued with encouraging results for 4 yr., some cars covering 40,000 miles without having to change the hearth.

It was evident that carbon should be kept as low as possible, around 0.30%, with silicon as low as possible, the nickel content should be about 2%, and the nitrogen 0.20%. This gives, with heat treatment, a tensile strength of 85,000 psi., with an elongation of 2%.

The welding to the sheet iron without preliminary heating is done with very soft plain iron electrodes, having 1.50% manganese. Low current density and plus polarity 3.25-mm. rod is used. When ferrochromium stocks ran short it was wondered whether aluminum could be used as a substitute. The greatest difficulty is that aluminum bestows brittleness upon the steel. With 6% chromium and 6% aluminum the alloy supposedly can withstand 2200 F (1200 C).

The superiority of chromium steel over the new alloy is quite evident, but the chromium-aluminum alloy is cheaper. Heat resistivity of the new alloy is 27 times that of cast iron but a third to a fifth that of chromium steel at 1650 F (900 C).

—J. Sissener. *Foundry Trade Journal*, Vol. 78, Mar. 28, 1946, pp. 341-345.

Damping Capacity and Fatigue of Metals

Condensed from "Journal of the Institute of Metals"

A special, highly accurate damping capacity tester was used to determine the changes in damping capacity during continuous vibration at surface shear stresses up to 22,400 psi. With aluminum and its alloys, there was a rapid increase in the damping capacity when a certain critical strain, dependent on heat treatment, was exceeded. The critical vibrational strain varied approximately with the limit of proportionality. The damping capacity-strain curves were similar for all aluminum alloys although the actual curves for each material were widely separated. Heat treatment as well as composition affected the position of the curves.

The damping capacity-strain curves for magnesium alloys resembled the curves for aluminum alloys. Copper had no critical strain. Quenched 0.6% carbon steel showed a critical strain, but no critical strain was observed in the quenched and tempered steel.

The changes in damping capacity during vibration at a stress above the critical value are associated with strain hardening and fatigue. Strain hardening produces a progressive decrease in the damping capacity while fatigue causes a gradual increase. If further work confirms this hypothesis, a rapid means will be available for determining the fatigue strength of metals and alloys.

It is believed that damping capacity will have little effect on the development of vibrational stresses below those stresses at which fatigue occurs, at least for aluminum alloys. Therefore, materials having a high critical strain and a low damping capacity at strains under the critical value may be the best choice for good endurance.

—R. F. Hanstock & A. Murray. *J. Inst. Metals*, Vol. 72, Feb. 1946, pp. 97-132.

NONMETALLIC MATERIALS

Design-uses of plastics, plywood, fibre, glass, rubber, ceramics, etc. as engineering materials. Composite metal-nonmetal combinations. New forms of nonmetallic materials.

What the Laminates Offer

Condensed from "Plastics"

In a broad sense, any material made up of layers bonded by a synthetic resin may be called a laminate, such as an overlay of a sheet of cellulose acetate on a document, or of paper on plywood. Here the separate layers can be seen. In a narrower sense, the laminates are materials made of stacks of resin-impregnated paper, cloth or other filler subjected to heat and pressure so that the components lose their identity, emerging from the press as a hard, compact homogeneous material.

The first resin used for laminating was phenol formaldehyde, which is still of major importance, either alone or modified with phenol furfural, aniline formaldehyde, etc. Melamine formaldehyde has made strides, and the silicones are coming along as binders. Fillers include paper, cloth, sisal, Fiberglas, asbestos and more recently, nylon.

The laminates have usually been engineering or utilitarian materials, but with more recent adaptations for table tops, cabinets and the like, they have entered the consumer goods field. Laminates dished in shallow curves are available as large as 20 by 30 in. For inner doors of refrigerators they have been made dished to a depth of 1 in. and 3/32 in. thick.

Laminate sheets can serve where subject to constant vibration, as in switchboard panels. They have high mechanical strength in relation to weight. Thus, the fabric-base type is good for pulleys and gears, being noiseless and strong, having an impact strength of 6 ft. lb. per in. of notch. They are useful for clutch cones, discs, tubes on which coils are wound, bearings for steel mills and ships, large caster wheels for hand trucks, self-lubricating bearings for meters, instruments and business machines.

Laminates are not only strong but odorless and act as moisture barriers. Water cooler fan blades, 5 to 6 ft. long, have been made of laminates, replacing metal. Greater cost is offset by superior resistance to erosion from the continuous water spray, by better absorption of vibration and smoother operation. A bent or broken blade causes little damage.

They act as good electrical insulation and are not affected by moisture or temperature changes. Paper-base laminates have been used as terminal boards, spacers and washers, and are easily punched. Laminates are available in many stock forms, such as sheets, rods, tubes, channels, angles and other simple geometric shapes.

A spinning bucket for the rayon industry achieved a tensile strength of 12,000 to 14,000 psi. and a flexural strength of 18,000 to 22,000 psi. One process is post-forming, whereby, though it is a thermosetting material, it can be manipulated into simple forms at high temperatures. It is used for parts often formed by metal spinning. Simple dies are needed, and it is possible to post-form a cup shape in which the depth bears the ratio of 0.75 to the horizontal radius.

Although the laminates of common grades cost from 42 to 82¢ per lb. as against 23¢ for aluminum, their lower density makes the laminates more economical on a volume basis. Aluminum has a specific gravity of 2.7 as against 1.35 for laminates.

—J. D. Nelson & L. V. Larsen. *Plastics*, Vol. 4, Mar. 1946, pp. 62-65, 311-313.

Impregnating Magnesium Castings

Condensed from "Iron Age"

By the use of sealers, castings can be used in spite of microporosity. Impregnation—forcing the sealer into and throughout the microporosity—is a new approach. Impregnation causes the sealing agent to become a definite part of the casting.

Sodium silicate (water glass) is accepted by many foundrymen as a satisfactory sealer. It is alkaline and, consequently, is reactive with such metals as zinc, aluminum and magnesium. Since it is a silicate and thus abrasive in nature, extreme care must be taken in cleaning castings not to impair delicate bearing surfaces.

Probably one of the most critical disadvantages of water glass is the fact that it is over 50% water. As the water leaves the solution, a gel forms, making it extremely difficult to completely dry or dehydrate an impregnated casting. Castings may pass a certain pressure test; on aging the residual moisture dries out, thus causing leakage to reoccur.

A common method of using water glass is to immerse the casting in a hot solution, about 190 F. This causes some superficial or surface penetration. In the case of reactive metals, it is believed that what sealing is achieved by this immersion is largely due to the corrosive action of the sodium silicate.

The desirability of a compound containing no volatile ingredients is apparent. Organic compounds based on vegetable oils have been found much superior to the silicates in this respect. China wood oil (tung oil) particularly has moderate drying properties and comparatively low viscosity.

Interchemical Corp. developed No. 988 metal impregnating compound which meets the requirements for a resin which is not a thermo-plastic, is not gas soluble, and does not use an explosive catalyst. It is reactive and will copolymerize with reactive monomeric styrene to form a desirable sealer.

Monomeric styrene is a volatile liquid having a boiling point just under 300 F. It is important that impregnated castings are not baked over 300 F (at atmospheric pressure) to avoid the loss of styrene before polymerization takes place. If baking can be done under pressure, loss will be minimized.

While the No. 988 resin-styrene solution is reactive, it is sufficiently stable for normal factory working cycles. Samples maintained at 68 F have remained stable for more than 3 months. Considering that a factory impregnating tank is cooled by water run through coils and has daily additions of fresh material, stability is perpetuated and no difficulty is encountered.

Copper and brass are reactive with monomeric styrene forming a compound that may interfere with its polymerization. For this reason there has been developed by Interchemical Corp. a special resin that

prevents the inhibiting effect of copper when mixed with styrene.

—Samuel A. Moore. *Iron Age*, Vol. 157, Mar. 14, 1946, pp. 76-80.

Preservatives for Wood

Condensed from "Purchasing"

Coal tar creosote is the standard wood preservative in the United States since out of 278 million cu. ft. of wood treated in 1944 over 96% was treated with creosote products. The Federal Government recommends use of coal-tar-creosote, creosote-coal-tar solution, or creosote-petroleum solution for treatment of wood in contact with the ground or water. For telephone and power line poles straight coal-tar-creosote only is recommended. However, for Douglas fir, hemlock and red cedar creosote or creosote mixtures may be used.

Because of scarcity of creosote, substitutes have been used. The three classes of substitutes are: creosote mixtures, toxic oils other than creosote, and water borne preservatives.

It is desirable to use at least 50% coal-tar-creosote in any mixture. Creosote-petroleum solution and creosote-coal-tar solutions have been used for cross ties for many years, but were used sparingly for poles. Creosote-petroleum-pentachlorophenol mixtures are of recent use for poles. There is also the possibility of using a mixture of water-gas tar, wood-tar creosotes and oil-tar creosote with coal-tar creosote.

Among the toxic oils that the armed services have used are solutions of polychlorinated pentachlorophenol in petroleum solvents. Tent poles and tent pins were treated by pressure and non-pressure impregnation methods while container plywood, boats, vehicles and other wood articles were treated by superficial methods with these preservatives. The toxity of pentachlorophenol appears to be 10 to 100 times greater than that of coal tar creosotes. From standpoint of toxicity, 5% solutions are sufficient.

Solutions of 3 and 5% pentachlorophenol in waste crank case oil have made a good record. Light oils usually penetrate wood better than viscous oils. Some petroleum solvents when treated with pentachlorophenol are likely to sludge and cause plant operating difficulties or dirty poles.

The cost of pentachlorophenol treating solutions is favorable alongside coal tar creosote. There is enough available in 1946 to prepare 30 million gal. of 5% treating solution.

Copper naphthenate and probably some of the other metallic naphthenates have considerable value as wood preservatives. They were used by the Navy on wood boats. Naphthenates are abundant, being by-products of the petroleum industry. Brush applications are only mediocre, but impregnation under pressure is satisfactory.

It stands to reason that where an entire pole is treated the life is longer than where merely the butt has been treated. Experiments also show that where the preservative has been made to penetrate under pressure, life is longer than when applied superficially to the surface.

—J. Oscar Blew, Jr. *Purchasing*, Apr. 1946, pp. 97-101, 338, 340.

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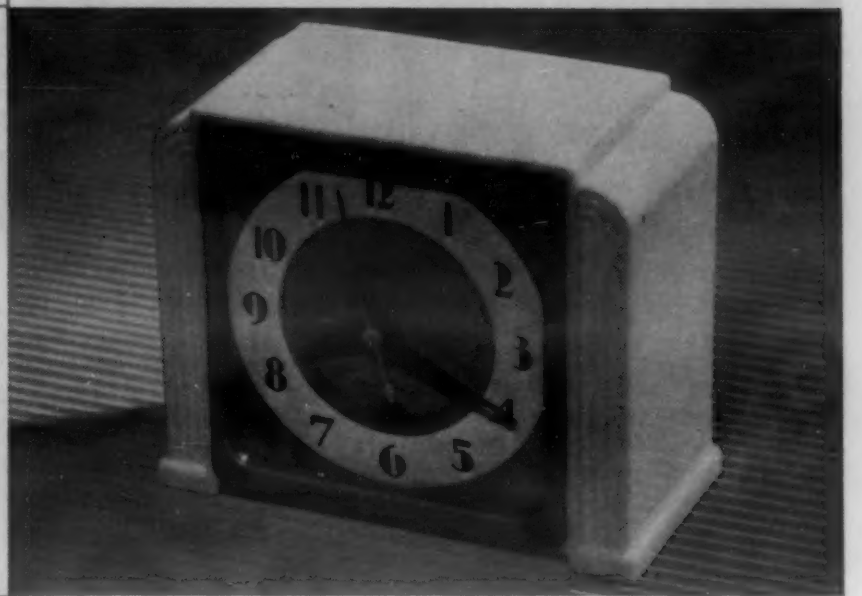

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This list is not complete but it does indicate why so many manufacturers standardize on Lustron today in a wide variety of applications, where performance and appearance both count.

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GENERAL PRODUCT DESIGN

Selection, applications and design of parts made by various fabricating methods or made of special materials. Properties and uses of finishes and coatings. Design and materials for specific products or fields. General engineering design trends or principles.

Machine Tool Materials

Condensed from "Western Metals"

The United States' recent war effort brought forth a production of machine tools valued in excess of 4½ billion dollars. The advent of new high-speed and carbide cutting tools made demands for higher spindle speeds and freedom from vibration which the machine tools of yesteryear could not answer.

One of the prime elements of machine tool construction is the gear. A great deal of care goes into the manufacture of gears. Heavy duty gears are manufactured from either direct hardening steel or from a case hardening type of steel.

The direct hardening gear steels most commonly used are AISI A-4145, A-2350, A-3150, A-3250, A-4345, A-4640 and A-8742. The steel used is fine grain, ASTM grain size 6-8. The gears are usually manufactured from forgings. Depending on the type of service, some gears are also made from castings or bar stock.

Material is customarily received in the annealed condition, and is rough machined. After rough machining the gears are either normalized or annealed to relieve machining stresses. The gears are then finish machined. On ground gears, grinding stock is left on outside diameters, tooth surfaces and bores. The gears are then ready for heat treatment.

Slow speed gears or other types of service which result in medium or low tooth surface loads are manufactured from steels heat treated to lower hardness values. These steels are usually AISI A-3140, A-4140, A-5140, A-6150 and A-8742. The stock is customarily rough machined and heat treated to 25-30 Rockwell C. The gear is then finished from the heat treated material.

The second major classification of gear materials is the case hardening type. Case hardened gear teeth are usually carried at higher surface hardness values than direct hardened gears. Case hardening is accomplished by several different methods, pack carburizing, gas or salt bath carburizing.

Several relatively new methods of hardening are by means of induction and flame hardening. Gears hardened by these methods are manufactured from 0.40 to 0.50% carbon steels. Some of the steels commonly used are AISI C-1141, C-1050, A-4145, A-3145 and A-8742.

Induction and flame hardening find excellent use in hardening bearing areas on shafting. Hardness values of 60-62 Rockwell C are obtained on such steels as AISI C-1141, C-1050, and 0.40 to 0.50% carbon alloy steels. Shafting and spindles which require high surface hardness are manufactured from the case hardening steels.

Some heavy duty lead screws are manufactured from 0.30 to 0.40% carbon alloy steel heat treated in the range of 30-40 Rockwell C. Lathe centers are ordinarily made from carbon tool steel hardened to 62-65 Rockwell C.

Great strides have been made in the processing of gray cast iron. Tensile strengths of the modern cast irons normally range from 20,000 to 60,000 psi. Special irons may be obtained that have a tensile strength up to 100,000 psi. Machine tools have utilized these modern cast irons.

—E. G. Green. *Western Metals*, Vol. 4, Mar. 1946, pp. 15-17.

Metal Glass Seals

Condensed from "Journal of Scientific Instruments"

After testing the expansion characteristics of alloys with 27.5 to 29.9 nickel and 16.53 to 18.49% cobalt for glass sealing alloys, a Kovar type alloy was chosen with 29 nickel, 17 cobalt, 46 nickel plus cobalt, 0.3 manganese, 0.15 silicon, 0.05 maximum carbon, 0.01 maximum phosphorus and 0.01% maximum sulphur. The carbon, sulphur and phosphorus should be kept low to ensure good sealing. The nickel content and the nickel plus cobalt contents should be kept within limits of ±0.5% to assure constancy. The over-all expansion between 73 and 932 F follows approximately the Hull-Burger-Navias equation relating composition and expansion.

As the temperature increases, the nickel cobalt alloys initially expand more than the molybdenum standard, but they decrease rapidly between 572 and 752 F. The transition temperature is 752 to 824 F, at which temperature the expansion increases rapidly. The expansion above the transition temperature is approximately independent of composition.

Between 73 F and the transition temperature, all curves show a hump. The only deleterious effect of this hump might be to cause tensile stresses in glass-metal seals. However, it is fairly constant, so a glass can be chosen to restrict this tension.

The expansion characteristics should be specified as well as the chemical composition. The specified expansion may be based on differential expansion measurements against a standard molybdenum rod. Starting with zero differential at 73 F, the curve should pass through a point 3×10^{-4} ($\pm 1 \times 10^{-4}$) above the molybdenum line at 932 F, the glass sealing temperature.

The stresses in metal-glass combinations were measured photoelastically. Suitable glasses can be made to match the expansion of the nickel cobalt alloy. The stresses in the metal-glass combination are low at all temperatures. If so desired, the stresses can be arranged to be compressive at all temperatures.

—G. D. Redston & J. E. Stanworth. *J. Scientific Instruments*, Vol. 23, Mar. 1946, pp. 53-57

Magnesium Alloys for Aircraft

Condensed from a Paper of the Society of Automotive Engineers

The late arrival of magnesium-base alloys in the fold of aircraft structural materials has been due to the fear on the part of the public of its inflammability, and its known susceptibility to corrosive elements. Recently, an alloying addition has been developed which is so potent that magnesium sheet is not affected to an appreciably greater extent than steel sheet, when subjected to incendiary ignition.

The development of superior fluxes and improved handling methods, as well as intelligent alloying, have created the present-day wrought alloys which may be considered corrosion-resistant materials even for exposure to salt atmospheres.

Those familiar with the metallurgy of magnesium are now convinced that the upper limit of mechanical properties has just about been reached for the present day family of alloys. Any marked increase in mechanical properties will have to be brought about in a new alloy system. Several laboratories have produced small quantities of experimental magnesium alloys with properties which, on a strength-weight basis, are superior to the highest strength commercial aluminum alloys.

Very recent developments in foundry

DESIGNING FOR DIE CASTING

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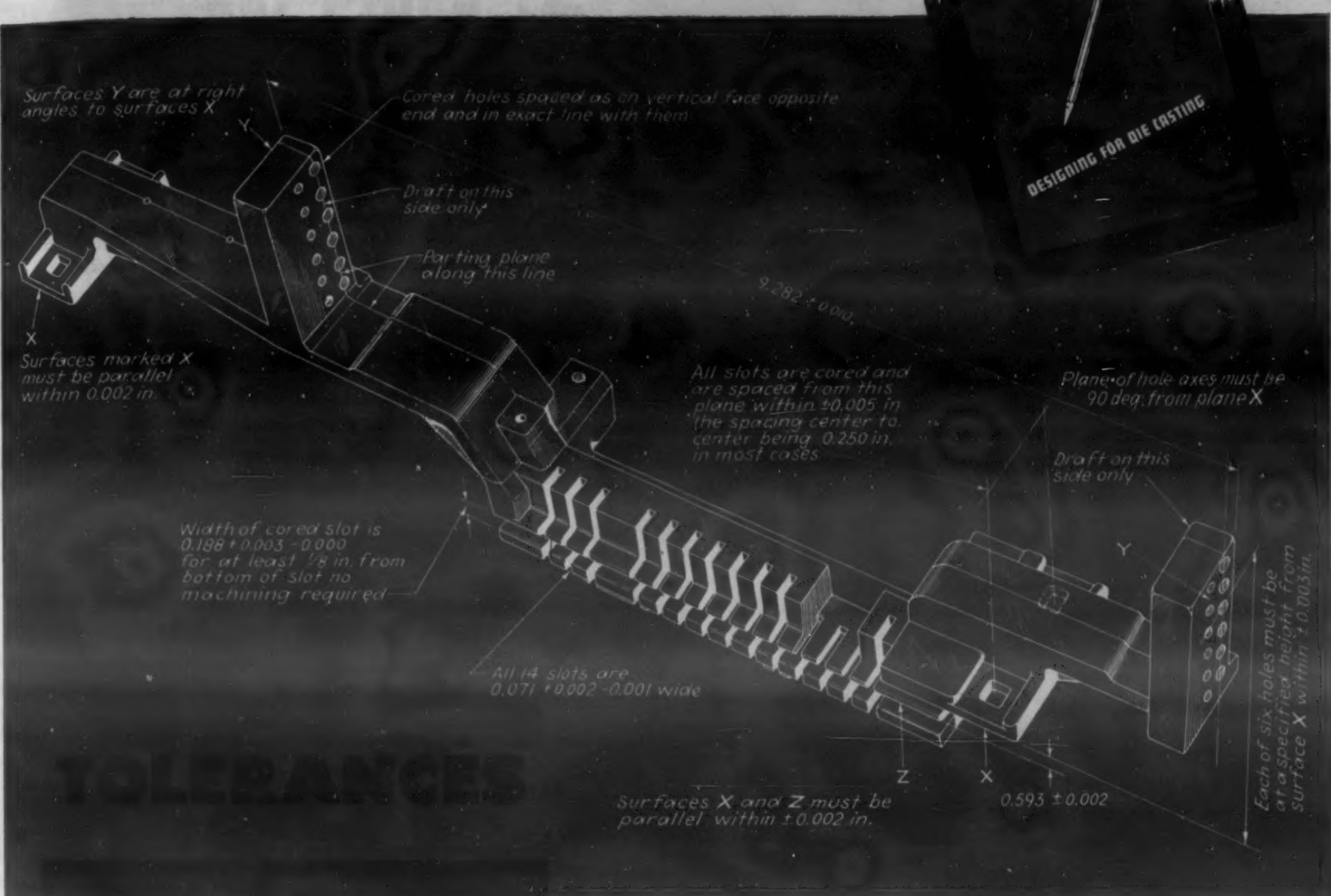

TOLERANCES

In designing die castings, ***never specify tolerances closer than are essential to meet requirements*** **since it may cost much more to hold close dimensions than to allow them to come within somewhat wider limits.**

Where close tolerances *are* essential, however, the die casting process is capable of doing a quite remarkable job. An outstanding example is the above *zinc alloy* die casting used in communications equipment. The tolerances shown on the drawing are all *as-cast*—and all critical holes are cored to tapping size! Each casting is checked in the special fixture illustrated to make certain that all dimensions are within the limits specified.

For *zinc alloy* die castings, the *minimum* tolerance—*as-cast*—is usually ± .001" *per inch* where the dimension is within solid parts of the die not having relative motion. Where the dimension is across a parting, or between parts of the casting formed by movable cores or slides, wider limits should be specified or provision for machining must be made.

Additional data on tolerances and other design considerations will be found in our booklet "Designing For Die Casting." To insure that you will get the most from your die casting dollar, ask us—or your die casting source—for a free copy of this booklet.

ZINC FOR DIE CASTING ALLOYS

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technology have pointed the way for the production of low-impurity magnesium castings. The low, or zero zinc-containing alloys, may, therefore, be used, because with low impurities these alloys have salt atmosphere corrosion resistance equal to the higher zinc alloys. The low-zinc alloys have better feeding characteristics, require fewer risers, and are easier to heat treat.

Groups interested in the further development of magnesium alloys have not been idle. The producers and fabricators of magnesium and the various branches of the armed services have been conducting research directed toward the improvement of magnesium alloys as structural materials for aircraft.

Besides the improvements mentioned, *i.e.*, flammability, corrosion resistance, quality of castings, uniformity of properties, and elevated-temperature characteristics advances have been made with the present family of alloys in regards to anodic coatings and paint systems, forming and welding techniques, and resistance to stress-corrosion cracking.

—J. C. DeHaven. Paper, *Soc. Automotive Engrs.*, Apr. 1946, 11 pp.

Tiny Engines

Condensed from "Die Casting"

Tiny engines, small enough to be held in the palm of the hand, have been developed to operate model airplanes, racing cars and boats. As the result of extensive study and experience, aluminum die castings are finding important use in model engines, especially where the choice lies between sand-cast or die-cast aluminum. Higher tensile strength, elimination of blow holes, reduction of machining operations, and greater uniformity of parts are a few of the reasons for preference of die castings.

Model-size gas engines are generally of two types: The two-cycle and the four-cycle engine, both employing a single cylinder. Die-cast aluminum cylinders, cylinder heads, pistons, connecting rods, crank cases, rocker arms, or carburetors may be found in many of the new models.

By use of a thin, steel liner, aluminum may be used for the cylinders. This contributes to lighter weight and better heat dissipation. Thermal conductivity of aluminum alloys ranges from 300 to 500% higher than for steel or iron. Die casting also reduces the amount of machining needed.

Materials for pistons and cylinders or cylinder liners must be chosen with the coefficient of expansion of the metals in mind. Some manufacturers prefer die cast aluminum, others cast iron or steel.

One of these midget engines has a single piece die cast cylinder and crank case. Total weight of the engine is 6½ oz. Die casting instead of sand casting reduced machining by 2½ times.

Another type is a five-cylinder, radial type engine consisting of 29 die cast components. Cylinder heads are die cast integrally with the cylinders eliminating an assembly operation. The engine weighs 22 oz. and develops ½ hp. at 3500 rpm.

—*Die Casting*, Vol. 4, Mar. 1946, pp. 20-22, 55-56.

MELTING and CASTING

Melting, alloying, refining and casting methods, furnaces and machines. Iron and steel making, nonferrous metal production, foundry practice and equipment. Die casting, permanent mold casting, precision casting, etc. Refractories, control equipment and accessories for melting furnaces.

Production of Beryllium Compounds

Condensed from a Paper of The Electrochemical Society

Beryllium compounds were first recognized by N. L. Vauquelin in 1798 during his analysis of the mineral beryl. He found that there existed a new element in beryl which differed from aluminum in that the hydroxide was precipitated when a potassium hydroxide solution of it was boiled.

The pure metal was first prepared by F. Wohler and A. A. B. Bussy in 1828 by reducing beryllium chloride with potassium. The methods of extracting a pure beryllium compound from the ore, however, have been studied for the last hundred years and there have been several hundred methods invented and patented but none has stood out as being the most economical or the most easily carried out.

Pure beryllium is a light metal of specific gravity 1.83, or about the same as that of magnesium. Its melting point (1287 C) is high for a light metal. Unlike magnesium or aluminum, it is usually quite hard and brittle.

Very recently advances have been made in making beryllium somewhat ductile by small additions of titanium or zirconium. This type of material is being hot rolled into sheet, and used as X-ray windows in which application it is said to be 17 times as transparent to X-rays as is aluminum. It is also being applied in other electronic devices.

Very recently beryllium has found application as an addition to magnesium and aluminum. Small percentages are added to magnesium alloys to prevent drossing and burning during melting as well to to make the cold metal less susceptible to ignition. Similarly, small percentages are added to aluminum to make it tarnish-resisting for applications such as cooking utensils. The addition alloy or "hardener" is supplied as 5% beryllium with the balance divided between aluminum and magnesium.

Beryllium found its important place in the industrial world as an alloying constituent with copper. There are alloys of various compositions, but the most prominent is an alloy of about 2% beryllium, 0.3% cobalt, and the balance copper. It has been said that beryllium is to copper what carbon is to steel.

The copper-beryllium alloy is of the precipitation hardening type, and can be rolled, drawn, stamped, cupped, spun, etc., while in a soft or annealed condition, and then, by a simple low-temperature heat treatment, the alloy is given a remarkable degree of hardness and tensile strength. In the annealed condition the hardness is about 85 Rockwell B and the tensile strength about 80,000 psi. Heat treatment, such as 2 hours at 600 F, gives it a hardness of guaranteed minimum 37 Rockwell C, and a tensile strength of guaranteed minimum 170,000 psi.

In addition to the 2% beryllium-copper alloys, a separate and distinct field of increasing importance are the high electric conductivity alloys containing about 0.50% beryllium, with the cobalt from 1.00 to 2.50%, and in some cases silver up to 1%; the balance is copper. These alloys in the fully heat-treated condition have electric conductivities of from 50% to 60% of copper, with a hardness of 92 to 98 Rockwell B. Strip of such alloys can be shaped and formed generally in the same manner as spring temper phosphor bronze.

These alloys are used in applications that require high conductivity, particularly for resistance welding electrodes and more recently for current-carrying springs and switch parts.

Before the war considerable work was being done on an alloy of beryllium and nickel. Strip of this remarkable alloy, heat treated from the cold rolled condition, has a tensile strength of 270,000 psi. and a Brinell hardness of 480 with an 8.80% elongation. It is expected that this alloy will soon be marketed.

Beryllium copper is very easy to cast by ordinary foundry methods, and castings in plaster have yielded remarkably good results. A number of different compositions are used as casting alloys, depending on the application.

The balance of this paper deals with the ore processes of which there are three of commercial importance in use in this country at the present time.

—H. C. Kawecki. *Electrochemical Soc., Preprint No. 89-11.*

Light Alloy Castings

Condensed from "Canadian Metals and Metallurgical Industries"

The last few years have seen the light metals "at war" and the aircraft industry has consumed practically all the world production of aluminum and much magnesium.

Aluminum has about one-third the specific gravity of iron, and when alloyed with such elements as copper, magnesium, silicon and zinc, produces materials with highly satisfactory mechanical strength, electrical and thermal conductivity and corrosion resistance.

Magnesium has approximately two-thirds the weight of aluminum. It is a good structural material when suitably protected against corrosion, and possesses excellent machining qualities. By alloying magnesium with aluminum and zinc, a range of mechanical properties is obtained, which on a strength basis, compares favorably with aluminum castings.

In the case of aluminum, castings represent 21% of total aluminum production,

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HOW IT WAS DONE AT GUELPH STOVE COMPANY

Guelph Stove Company, one of the leading Canadian manufacturers of stoves and furnaces, eliminated costly waste in the cleaning room by installing a No. 3 Wheelabrator Table and a 27" x 36" Wheelabrator Tumblast to handle their entire production.

In addition to removing sand from castings in the green stage, both machines are used for cleaning preparatory to enameling. (See illustrations at right.)

Twelve tumbling mills were eliminated . . . breakage of fragile stove parts became a thing of the past . . . production capacity was increased using only a fraction of the former floor space . . . and cleaner working conditions were maintained.

A one-minute cycle through the No. 3 Wheelabrator Table is sufficient to remove foundry sand from stove plate and furnace castings. Many tons of castings of the type shown in the picture above are cleaned daily in the rough stage and prior to enameling.

This 27" x 36" Wheelabrator Tumblast, operating nine hours daily, cleans all of the small stove and furnace parts. Loads weighing several hundreds of pounds each are cleaned in from two to six minutes.

Notice the bright, clean, silvery appearance of the Wheelabrated castings in the conveyor of the 27" x 36" Wheelabrator Tumblast. This load of gray iron castings was cleaned in just four minutes.

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while castings represent 97% of total magnesium production.

The principal sand-cast alloys in general use are listed. AC 350, in the heat-treated and quenched condition, develops the highest mechanical properties of any aluminum sand-cast alloys. Aluminum articles have a thin oxide film approximately 0.0000004 in. thick; this film is self-healing. The film may be increased electrochemically by the Alumilite process, in which the article is made the anode in a sulphuric acid solution. Passage of the electrical current deposits oxygen on its surface, which combines with the metal, increasing the film thickness to 0.0008 in.

In the production of commercial castings, sand, permanent mold, die and centrifugal casting are used. Centrifugal casting of light metals is successful if due regard is taken for the particular characteristic of both aluminum and magnesium.

The most commonly employed method of checking casting assemblies is by breakdown tests, in which the parts, after machining, are dynamically tested to destruction and a measure of the stresses which service loading will impose is obtained.

In the stress-coat method of stress analysis the parts are covered with a brittle lacquer, applied under controlled atmospheric conditions. The parts are stressed by external loading and the distribution of stresses is indicated by a variation in the degree of cracking in the lacquer coating.

A magnesium alloy containing 9 aluminum and 2% zinc is the one preferred where the mechanical properties are suitable because of its adaptability for both sand and permanent mold casting. An alloy containing 6 aluminum and 3% zinc is used largely for sand castings. These alloys are used for bomber wheels, hubs, rims and for aircraft window frames and numerous engine parts.

While secondary aluminum may be used for many casting alloys, if great mechanical strength and strong corrosion resistance are needed, traces of contaminating elements must be avoided.

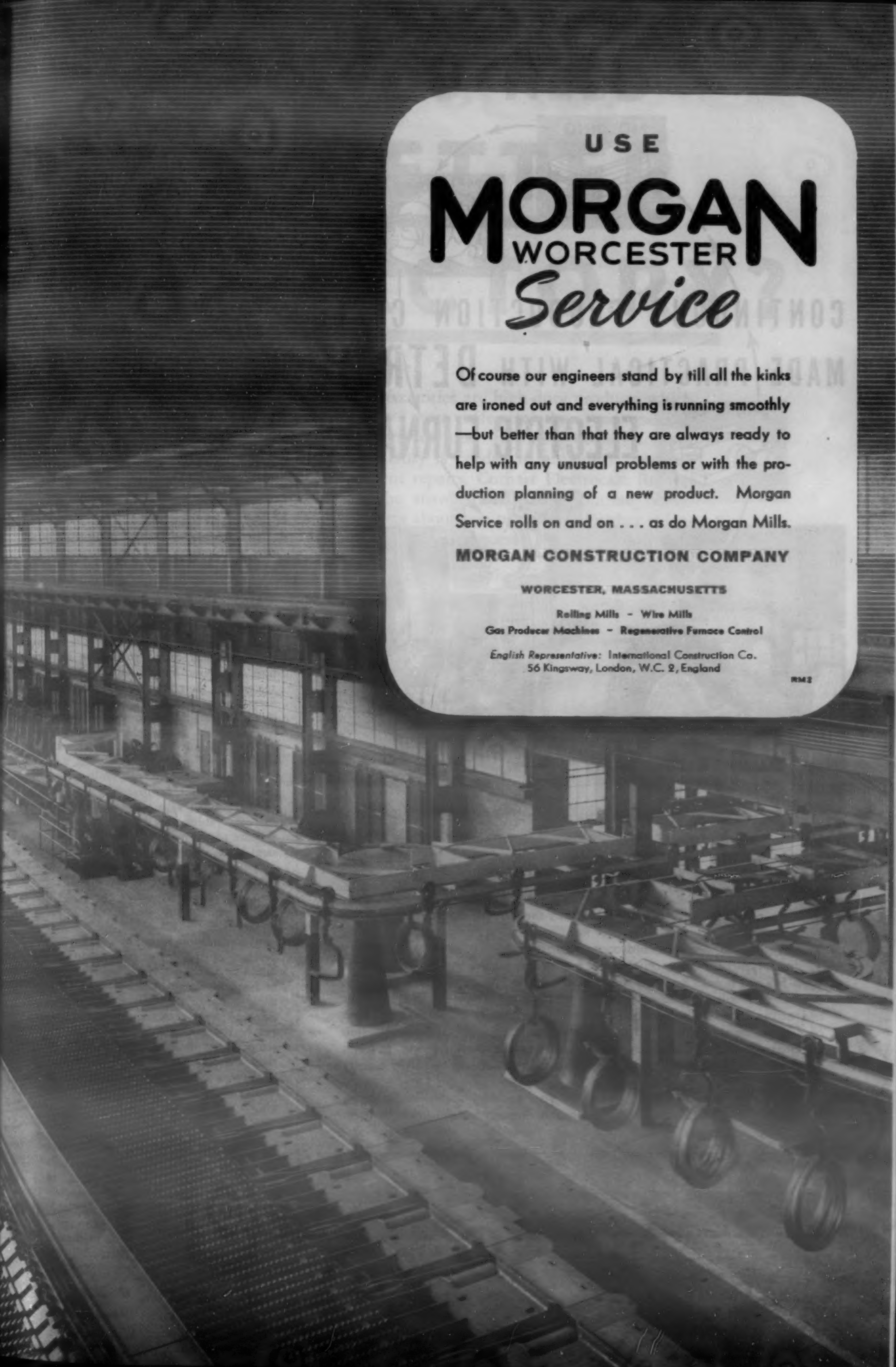
Postwar applications are indicated for the transportation, food, heavy and light machinery, electrical, chemical and building and construction industries.

—G. M. Young. *Can. Metals & Met. Inds.*, Vol. 8, Dec. 1945, pp. 27-33.

Gassing of Bronzes

Condensed from "The Foundry Trade Journal"

The absorption by molten bronze of gases from furnace atmospheres is widely recognized as a major source of porosity. It is now generally accepted that hydrogen is the chief cause of gas porosity, and that the metal may be freed from this trouble by melting it under oxidizing conditions. It is much less known that hydrogen may be absorbed by the molten bronze during casting, by reaction with the surfaces of sand molds, cores, etc.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Of course our engineers stand by till all the kinks are ironed out and everything is running smoothly —but better than that they are always ready to help with any unusual problems or with the production planning of a new product. Morgan Service rolls on and on . . . as do Morgan Mills.
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56 Kingsway, London, W.C. 2, England
RM2

Lepp (International Foundry Congress, Prague, 1933, 95-118) showed that this source of gas porosity in sand cast bronzes is controlled by the moisture content of the mold in relation to the permeability of the sand.

It was also shown (W. A. Baker, F. C. Child & W. H. Glaisher, *J. Inst. Metals, Vol. 70*, 1944, p. 373) that with degassed phosphor bronze for sand-castings, the absorption of gas at the surface of the casting during pouring may exert a beneficial effect if the casting is of complicated shape, so that complete feeding of isolated heavy sections would be impossible.

The absorbed gas is liberated first on solidification of thin sections and near to the surface of the casting, and sets up an internal gas pressure which assists feeding in the central and warmer parts of the heavy sections. The amount of gas absorbed from this source increased with the phosphorous content and with pouring temperature, while the reaction was eliminated completely by addition of 0.3% silicon to the bronze. Many cases of serious porosity and poor mechanical properties in bronze have been traced to gas absorbed by reaction with combined water present in sand molds, sand cores, etc.

In applying to regular production practice, a degassing and slow-pouring treatment devised by the author (W. T. Pell-Walpole, *J. Inst. Metals, Vol. 70*, 1944, p. 127; W. T. Pell-Walpole & V. Kondic, *Ibid, Vol. 70*, 1944, p. 275), several foundries reported that phosphor bronze chill sticks made by this process still showed tin sweat, segregation patches in the fracture, and poor mechanical properties. Inspection of their practice showed that these firms were pouring the metal through molded sand basins instead of using the recommended Salamander pouring basins.

A comparative test was made. A melt was prepared under the degassing flux and poured into two 2-in. dia. chill molds, one stick being poured through a molded sand basin (bonded with a pure colloidal clay), the other through a clean preheated Salamander pot. The ingot poured through the sand basin showed exudation, had a density only 8.60 and tensile strength of 45000 psi., while that poured through the Salamander pot was quite clean with a slightly sunken top, had a density of 8.76 and tensile strength of 61,000 psi.

The effect of variation of baking temperature on the degree of gas porosity produced by reaction was studied for a number of bonding agents, and bonded sands. Organic bonding agents, whether tested independently or admixed with sand, could not be baked above 390 F, since at higher temperatures these substances char and lose their bonding properties.

Clays or clay-bonded sands can be baked at much higher temperatures, and one bond, aluminous cement, typical of this group, was tested up to 1650 F. The extent of gas porosity produced by the reaction on pouring, diminishes markedly with increase of baking temperature for all bonding agents, presumably due to a decrease in the amount of combined water retained. Oil bonds gas least, cereal bonds next and clay bonds most. The finer the grade of sand the more the gassing due to increased clay content and decreased permeability. The

temperature reached at the reacting surface is determined chiefly by the pouring temperature. The higher the temperature the greater is the gassing. Gassing is most severe in high phosphorous bronzes, but decreases considerably when the phosphorus content is reduced to 0.25% or less. Gassing also increases slightly with tin content, but an increase in lead reduces gassing and the leaded bronze appears to be immune.

—W. T. Pell-Walpole. *Foundry Trade J.*, Vol. 78, 1946, Jan. 24, pp. 87-89; Jan. 31, pp. 105-108; Feb. 7, pp. 147-150; Feb. 14, pp. 163-167; Feb. 21, pp. 209-210; Feb. 28, pp. 235-238, 240.

Permanent Mold Aluminum Castings

Condensed from "Steel"

Permanent-mold castings weigh less than sand castings of the same part, and have closer dimensional tolerances, smooth surfaces, fine grain structures, and greater tensile strengths. There is less metal to be removed in machining, and the metal is removed faster.

The aluminum foundry of Aluminum Industries, Werk Road, Cincinnati, Ohio, has more than 600 molds in all sizes, and casts 26 different aluminum alloys. Normal capacity is about 2,000,000 lb. per month. Permanent-mold castings constitute three-fourths of this total, the remainder being sand-mold castings.

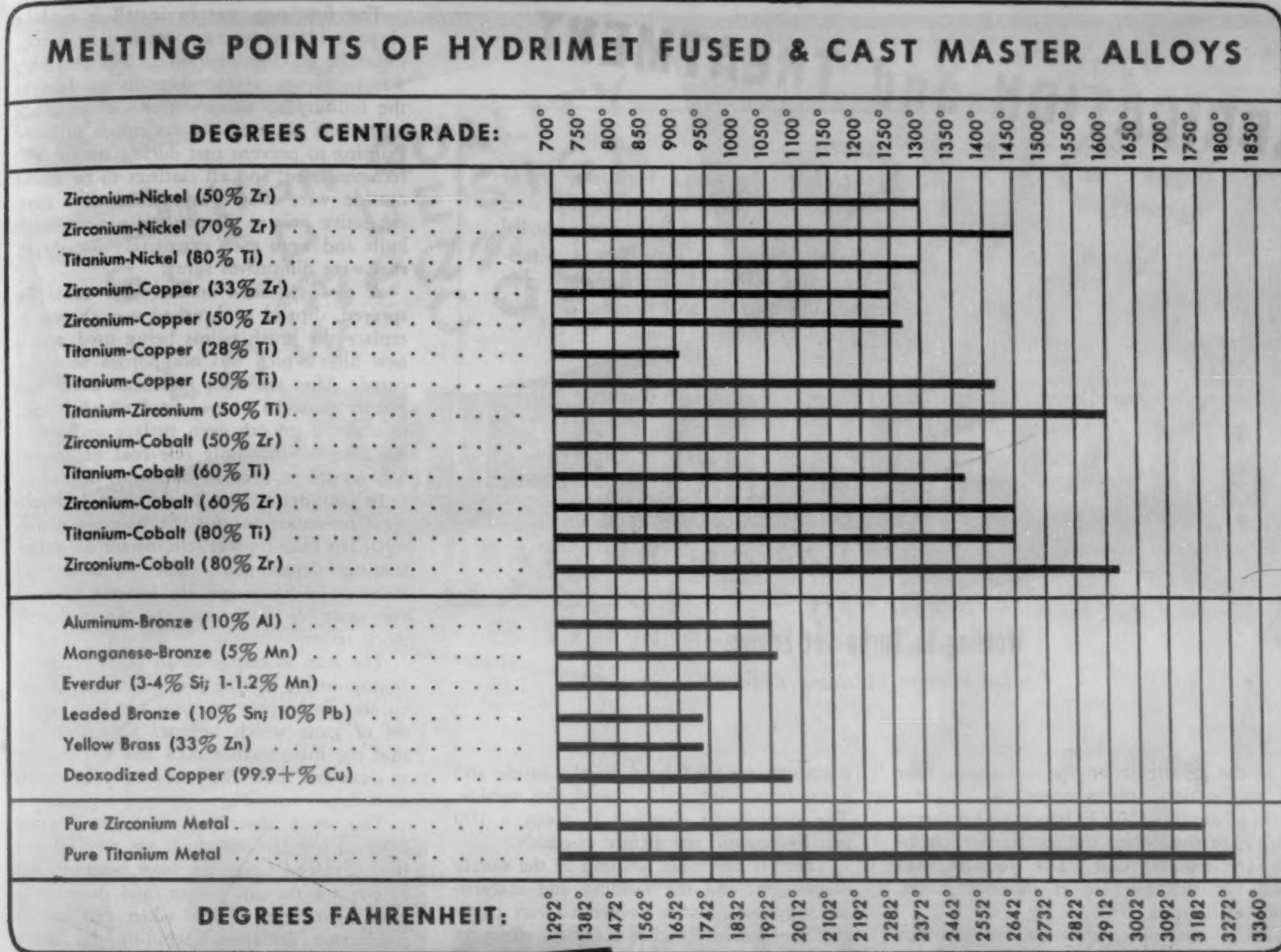
There is a battery of 20,000-lb. reverberatory furnaces, with automatic temperature control. Zirconite bottoms are used, extending life of bottoms from three months to a year. There are also ten 2,000-lb. rotary melting furnaces and some 1000-lb. and 350-lb. tilting furnaces. The trend is toward increased use of the tilting furnaces with complete automatic control, gas or oil fired.

Aluminum ingot or scrap is melted in a reverberatory furnace. Alloying elements are added to get the composition desired. Using a continuous mold conveyor with automatic cooling and discharge, 20,000 lb. of metal are cast into ingots in 2½ hr.

A barrel-type device, with a series of longitudinal bars made from rolled-steel angle sections, is arranged directly over the conveyor at the pouring station. The entire device revolves in synchronism with movement of the conveyor so as to cover the space between molds by an inverted angle. As the molds pass under the pouring spout, the continuous stream of molten metal is so directed that it is shifted quickly from one mold to the next, without any metals falling between molds. This has resulted in 80% less dross loss, 350 lb. more good metal per heat, 90% less maintenance cost on mold conveyor and molds, and saving of 50 ingot-molds per month.

Ingots are remelted in the rotary- or tilting-type furnaces. The molten metal is poured into 600-lb. pots, where it is held until ladled into a permanent mold. Each pot serves two molding stations. Gates and risers are cut off, and castings are heat treated in an elevator-type furnace, with quench tank located directly below.

—Hiram Brown. *Steel*, Vol. 118, March 4, 1946, pp. 124-126.



Many new alloy combinations now possible

. . . Also elimination of hot working

Study the above chart carefully. Note for yourself the many new alloy combinations Hydrimet Fused and Cast Master Alloys now make possible. Alloy combinations which may give you just the special characteristics for which you have been searching.

But this is not the whole story. Hydrimet Fused and Cast Master Alloys often can eliminate hot forging or hot rolling operations, previously required before fabrication. Their purity is so high that, when added to other molten metals, they show extremely high recoveries and usually eliminate completely all problems of gas porosity. Thus, the alloy combinations produced are sound, homogeneous ingots, in many cases satisfactory for direct fabrication purposes.

Data Sheets, giving specific characteristics and recommended melting and heat treating practices, are available for all the Hydrimet Fused and Cast Master Alloys listed in the above chart. Other special Fused and Cast Master Alloys, ternary as well as binary, can be produced to suit individual requirements. A wide range of Master Alloy Powders also can be supplied. *Write for information to Dept. A.*

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Welding In Turbo-Jet Engine

Condensed from "Welding Engineer"

In the jet aircraft engine the intense heat of combustion creates operating temperatures of around 1500 F, hence heat-resistant alloys are needed for the combustion chamber and exhaust unit. The stainless steel used for this purpose is in sheet form, some as light as 0.022 in.

Being austenitic, these alloys are not heat treatable and are also stabilized alloys. Hence, no increase in hardness nor loss of ductility occurs from the heat of welding and, because of stabilization, there is but very little loss of corrosion resistance when welded.

There are over 500 welded joints in the I-40 jet engine, most of which are joining sheet metal. Thus, the distortion problem is acute, particularly because of the higher coefficient of expansion of stainless alloys.

A butt joint would save weight in an airplane, but where thin sections are joined to heavier sections stress concentrations would develop in the thinner section, possibly causing failure in service. Fusion welding of a butt joint would also cause distortion. Therefore, a lap joint is used where the flanges are welded to the exhaust casing or the ring holders as well as to the flame tubes, seam welding being used.

Atomic hydrogen welding is employed extensively on many of the longitudinal seams to provide a flush joint without grinding. Provisions must be made for possible distortion and its reduction by proper fixtures and handling. In some cases the welding sequence can be used to reduce distortion and the machining sequence to correct it.

The most complicated assembly is the combustion chamber, there being 14 of these chambers arranged in circular form. The assembly is checked on a go-no-go fixture, then set up on a boring mill for the machining of the rings. The ring-and-tube joint is welded from the inside of the flame tube and the metal is melted to form a smooth rounded bead on the inside and a uniform filler weld around the outside. The combustion chamber is given a 100 psi. hydrostatic test before assembly.

There is much arc welding in the nozzle diaphragm, and the welding and machining sequence must be controlled very closely. The nozzle area has a critical effect on the unit's operation and thus the diaphragm must be scrapped if it is not within the drawing tolerances.

The turbine shaft is of SAE 4140 steel welded to a wheel forging of special alloy steel. The chromium-molybdenum steel shaft is 3¼ in. in diameter. It is welded in about 2½ min.; overall time, including handling, is 10 min.

Of all the flash-welded joints made on the I-40 turbine wheel, only one resulted in failure, and this during the high-speed test before final assembly.

—W. J. Campbell. *Welding Eng.*, Vol. 31, Mar. 1946, pp. 33-35.

Painting Machine Parts

Condensed from "Industrial Finishing"

A survey of a company's manufacturing procedure, with emphasis on the finishing departments and their interrelation with the rest of the factory, led to the conclusion that antiquated methods were being used. In recommending changes and new installations, all precautions for safety were taken into account. The objective was to eliminate rust; to do away with brushing methods as far as practicable; and to adopt more modern methods for cleaning, spraying, dipping and baking in order to get a more desirable and durable finish at a lower cost of production.

The first step was to install a modern abrasive blast-cleaning room and to discontinue the pickling operation. The next step was to secure a smoother cast surface at the foundry so as to cut down on filling operations required by the rough surfaces. Priming to prevent rust during storage was recommended, and all castings to be stored outside were first sprayed with this rust-inhibitive primer. Portable dip tanks were built and were used extensively for shapes that were difficult to spray.

A new synthetic enamel that could be sprayed, dipped or brushed was chosen to replace the brush paints being used, and a new filler which was non-porous was procured. After the filler had been selected, a primer standard was adopted which helped to make a smooth even surface and sealed the filler so that only one coat of enamel was needed to produce the finish desired.

In considering the layout, new locations were recommended for the painting activities. The foundry was selected for the prime coating department. The sanding and finishing departments are located close to the assembly floor and the finished-parts stock room.

The man in charge of all paint materials is responsible for the proper mixing of the paints. Each spray operator has a duplicate set of guns which he uses alternately, so that the maintenance man has ample time to clean and make the necessary adjustments each day.

The setup described represents a preplanned installation which has worked and paid dividends. Savings have been effected to pay for the equipment, and during the past eight years it has taken care of all production demands, including the heavy peak loads brought on by war work.

—C. Raymond Syer. *Ind. Finishing*, Vol. 22, Mar. 1946, pp. 36-50.

Lead-Tin Plating

Condensed from "The Monthly Review" of the American Electroplaters' Society

Protective coatings of lead-tin alloy, known as terne plate, have been applied to steel by the hot dip method for many years. During World War I Broff developed a method for electroplating a 50-50 alloy from the fluoborate bath, and in 1921 Haring and Blum found it relatively simple to deposit alloys containing approximately 50% lead and 50% tin.

The increasing commercial use of electrodeposited lead-tin alloy made desirable a simple, reliable method for plating in the lower ranges of tin. As a result of investigations, a method has been developed by means of which lead-tin alloy, containing any desired amount of tin from 5% to 60%, may be plated with a high degree of uniformity.

Lead-tin alloy may be plated by using either dual anodes or alloy anodes. The term dual anodes means the use of separate anodes of pure tin and of pure lead, the current flow to each being controlled separately. Alloy anodes are composed of lead and tin in predetermined ratios. For

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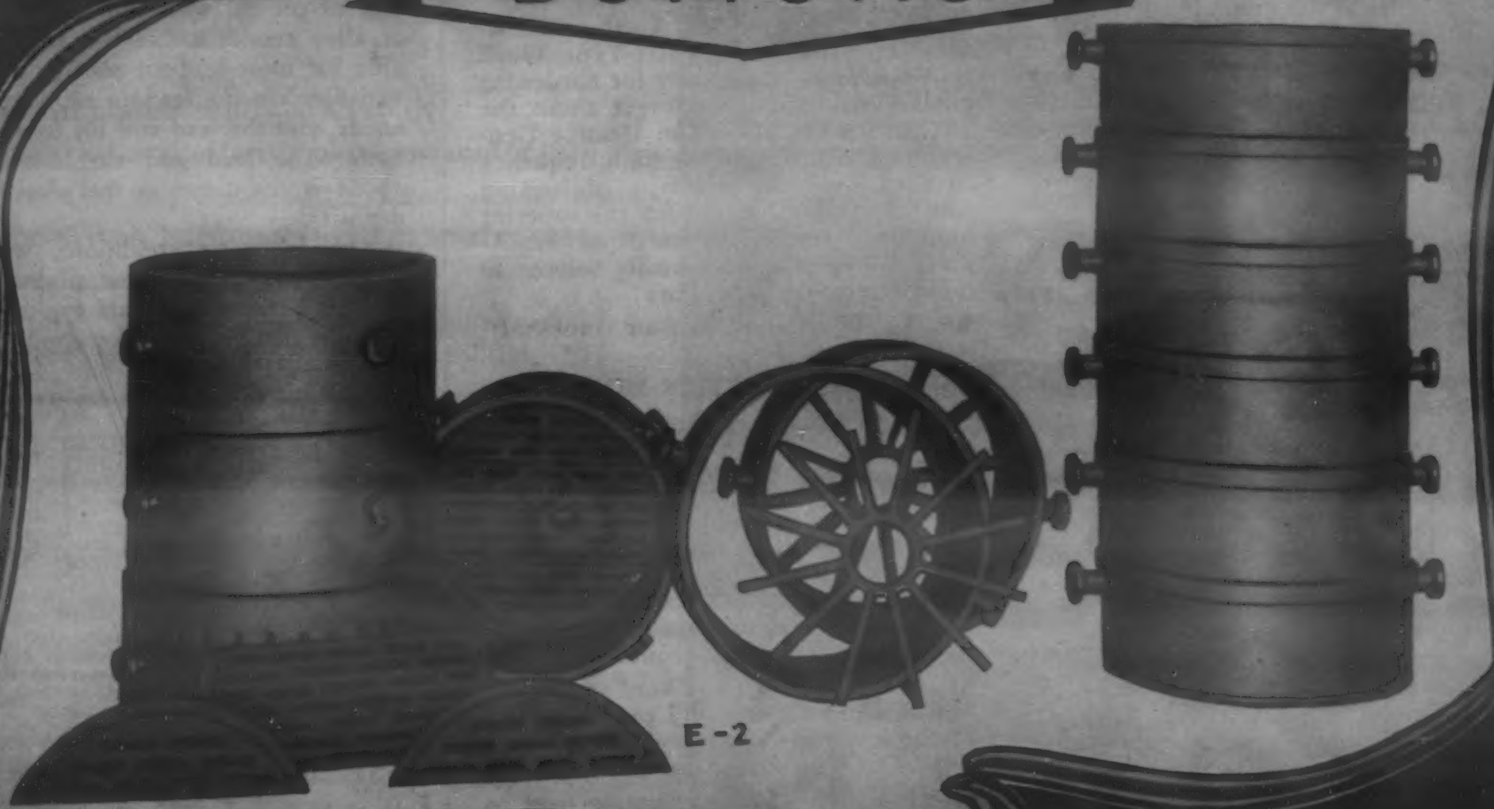

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THERMALLOY sectional baskets and bottoms for pit type carburizing furnaces are of correct design for direct quenching when necessary. Spider bottoms are removable and adjustable to permit desired spacing for maximum loading; they are also reversable for control of warpage.

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HEAT AND CORROSION RESISTANT CASTINGS

most lead-tin alloy plating, the alloy anode method is preferred because it is simpler to use.

The electrolyte employed in the deposition consists of a solution of lead fluoborate and tin fluoborate, to which is added an addition agent. The details for plating by the dual anode method have been developed only for deposits containing 90% lead and 10% tin, but alloys of any other composition could be plated if appropriate changes were made in the bath composition and operating conditions. Bath composition, acidity, temperature and current density are the same for the dual anode and the alloy anode methods.

In addition to these factors, in the dual anode method it is necessary to control the surface areas of the lead and tin anodes as well as the currents impressed on the anodes.

Experimentation shows that the proportion of tin in the deposit can be increased by increasing the temperature, increasing the tin concentration in the bath, increasing the amount of agitation, or by increasing the cathode current density. The greater ease of control which results from the use of alloy anodes makes this method preferable for most lead-tin plating, as the only variables are the lead-tin ratio in the alloy anode, and the lead and tin contents of the bath. The lead and tin content of the anode is the same as that desired in the deposit.

The following conditions, which have been found suitable for plating a 90% lead-10% tin deposit, are typical for lead-tin alloy plating with alloy anodes.

Bath Composition	g/l	oz/gal
Total tin	10.0	1.34
Stannous tin	9.0	1.21
Lead	90.0	12.06
Free fluoboric acid	40.0	5.36
Free boric acid	25.0	3.35
Glue	0.5	0.067

Temperature—70-100 F
Current density (cathode)—30 amps/sq. ft.
Anodes—90% lead-10% tin, cast
Ratio of anode to cathode areas 2:1

—A. E. Carlson & J. M. Kane. *Monthly Review, Am. Electroplaters' Soc.*, Vol. 33, Mar. 1946, pp. 255-260.

Gas Cutting Machines

Condensed from "The Welding Journal"

The oxyacetylene cutting process continues to amaze us with an endless offering of new developments. The gas cutting process meets industry's demand for increased accuracy and speed with more fully automatic operation. Today we find fabricators cutting holes to size for tapping without reaming; steel mills installing specially designed hot cut-off machines to operate on transfer tables for use on billets and rolled shapes, hot piercing of tube stock, and various materials slit to specific widths.

Many of the headaches of the past have become profitable business. Many mills are now mining spills, skulls and buttons, and cutting them to charging box size. The natural obstacles to the successful cutting of

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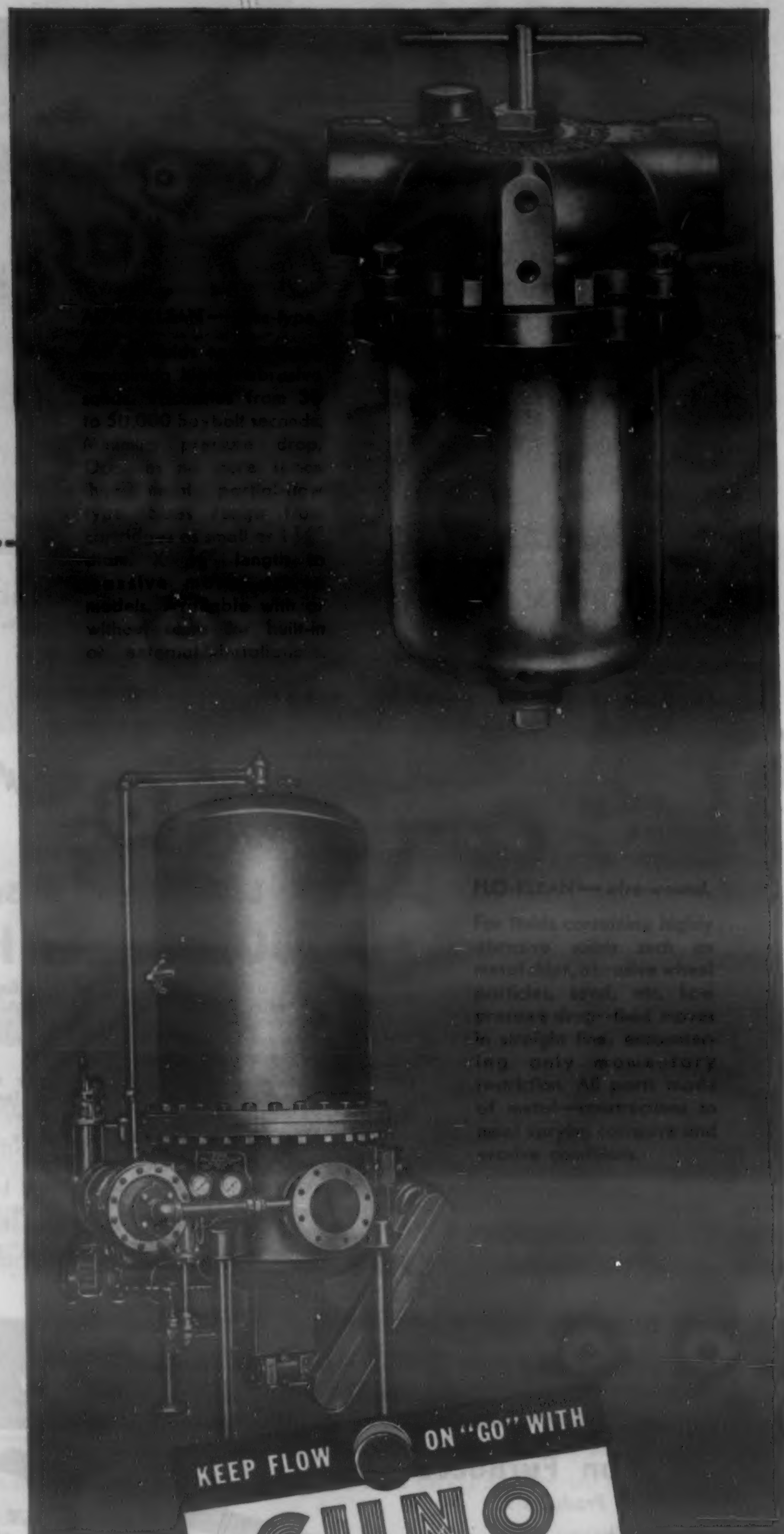

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- ☐Fuel Oil
- ☐Fuel Tar
- ☐Gases
- ☐Gasoline
- ☐Grease
- ☐Grinder Coolant
- ☐Hydraulic Oil
- ☐Japan
- ☐Lacquer
- ☐Lubricating Oil
- ☐Machine Tool Cutting Oil
- ☐Machine Tool Hydraulic Oil
- ☐Machine Tool Lubricating Oil
- ☐Nitrocellulose Solutions
- ☐Oils
- ☐Paint
- ☐Pyroxylin
- ☐Quenching Oil
- ☐Resins
- ☐Rust Proofing Compounds
- ☐Sizing
- ☐Solvents
- ☐Spray Systems
- ☐Tar
- ☐Test Stand Lubricating Oil
- ☐Varnish
- ☐Washing Compounds
- ☐Water
- ☐Wax

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stainless steel have been overcome. The electronic tracing device is now a reality, and machines that will cut in vertical and overhead planes are beginning to attract attention.

Machine cutting of scrap, the removal of cobbles from mills, "slicing up" furnace spills with the oxyacetylene process, hot cutting as part of the rolling operation, are all in use, and are highly regarded as economical and time-saving applications.

To the problem of cutting extremely heavy thicknesses of steel which are beyond the limit of any torch, the oxygen lance provides a ready answer. The procedure is simple; the steel is brought to a bright red heat, the end of the lance is brought into contact with it, and the oxygen valve is opened. The lance pipe directs oxygen to the preheated part of the work, and the oxidation of the steel and the propagation of the cut are continued by the heat liberated through the steady combustion of the parent metal and the oxygen.

Postwar production plans must utilize proven wartime developments, for as industrial fields of endeavor grow larger the demands will become more complicated. It takes vision backed up by plenty of courage and lots of hard work to do something progressive. Those who have the courage and the will to work out new production schemes, employing gas cutting, will find ready and willing assistance from the gas and apparatus supply companies.

—R. F. Helmkamp. *Welding J.*, Vol. 25, Mar. 1946, pp. 213-222.

Effect of Cooled Lubricants on Tool Life

Condensed from "Zeitschrift des Vereines deutscher Ingenieure"

It had been found that the cooling below room temperature of the coolant and lubricants of the tools in machining metals has an excellent effect on the life of the tools. Experiments in this direction have shown that the life can be increased 100% and more; a table is given for high-speed steels showing that increases in tool life of from 24 to more than 100% are possible if the temperature of the coolant is brought down to 35 to 45 F (2 to 7 C), in some cases even only to 68 F (20 C).

The amount of lubricant in these experiments was not increased and was the same as in normal cooling, that is, 5-12 *l. per min.* The lower temperature does not only reduce the temperature at the cutting point but, depending on the material, also the notch-impact toughness is reduced.

Another advantage can be obtained by increasing feed and cutting speed and thus bettering production instead of taking the savings in longer tool life. Surface quality, absence of oil vapors, and the saving of oil are incidental advantages; the tolerances of the work are not impaired by using low temperature cooling.

—G. Pahlitzsch. *Z. Ver. deut. Ing.*, Vol. 88, July 8, 1944, pp. 365-371.

TESTING and INSPECTION

Testing methods and equipment for physical and mechanical properties, surface behavior and special characteristics. Radiographic, spectrographic, identification, metallographic, dimensional and surface inspection. Stress analysis and balancing. Specifications, standards, quality control.

Testing of Highly Loaded Steel Bearings

Condensed from a Paper of the Transactions of the Society of Automotive Engineers

In order to reduce the time and expense involved in the testing of bearings in full-scale engines, the Wright Aeronautical Corp. has established an extensive supplementary program of bearing testing in laboratory rigs. These test rigs are extremely useful in the evaluation of specific properties of new bearing materials, designs and lubrication systems.

The load-carrying capacities of various bearing materials are determined in a test rig employing bearings identical to the crankpin bearings used in production engines. In a rotary aircraft engine the load travels around inside the bearing instead of being a reversing load, such as occurs with a single cylinder.

To simulate this condition in a test rig, the test bearing is assembled into a bobweight which is carried on a crankpin. This bobweight is kept from rotating with the crankpin by means of a train of gears.

Normally, the test bearing consists of a steel back with a bearing line, approximately 0.020 in. thick, bonded to the I.D., and the following test procedure is used: Prior to each test hot oil is pumped into the bobweight for one hour before starting the test, thereby eliminating any unequal expansion at the beginning of the test. Oil of 120 S.U.S. viscosity is supplied to the crankshaft at 185 F and 70 psi. pressure. The crankshaft speed is increased in 200 rpm. increments each 15 min. from 1000 to 2600 rpm. and in 100 rpm. increments each 20 min. from 2700 rpm. until the end of the test. At each speed, readings are taken of rpm., main oil pressure, pinion bearing oil pressure, oil flow through the test bearing and total flow, oil-in and oil-out temperatures, friction torque and watt meter.

It is interesting to note that tests made using a dive dummy engine showed good correlation of results with those of this laboratory test rig.

The friction and lubrication characteristics of highly loaded sleeve bearings are investigated on a four-bearing friction machine of the U. S. Bureau of Standards design. This machine consists of four test bearings contained within a housing which floats on the horizontal test shaft and acts similar to a cradle dynamometer. Load applied equally to the two inner bearings is taken equally by the two outer bearings since they are symmetrically spaced. An automatic load release is incorporated in the hydraulic loading system which, through a pin and micro-switch, actuates a solenoid-operated load relief valve, thus making possible the inspection of the test bearings at the earliest signs of seizure.

Before making the test runs the bearings are subjected to a 2-hr. run-in. In this test the load is held constant and the speed increased from 1000 to 5000 rpm. in increments of 1000 rpm. The unit loads used in these runs were 0, 500, 1000, 2000, 3000 and 4000 psi. The machine is operated at a given load and speed until the bearing thermocouple readings are constant. The data are recorded and operation is continued at the next higher speed.

The fatigue life of various bearing materials and also of various designs of splines on master rod bearings is evaluated on a test rig which provides a method for deflection by means of a 1½-in. dia. load roller inserted through the bore of the bearing while supporting the bearing on two power driven rollers. A production bearing is used for spline strength evaluation, while the same size bearing without splines is used for bearing material evaluation.

In the former tests, recesses are provided in the rollers for spline clearance. Load is applied to the roller through a yoke and coil spring which is calibrated for loads up to 1000 lb. Dial indicators contacting pins in the yoke measure the bearing deflection under load. The speed of the driving rollers may be varied from 150 to 700 rpm.

The test bearing is partially submerged in oil (SAE 30) while running. Periodic inspections of the bearing are made, the running time varying from 30 min. to 1 hr., according to the type of material on test. All tests are run at 700 rpm.

Bearing corrosion tests are conducted on a small laboratory machine developed by the Shell Development Co. of Emeryville, Calif. The machine consists of a steel cup filled with oil in which a steel disc is rotated against three flat bearing specimens supported on ball pivot holders. These specimens operate as Kingsbury thrust bearing shoes to provide hydronamic lubrication. The oil is heated by an electric heater, which is controlled by a thermoswitch. A graphic temperature recorder has been found useful, particularly since the test may be run at night with no observer present.

Conditions for this test are given in a table, and it is noted that satisfactory bearings are checked in full scale engines.

A simple dry wear test has been devised that yields relative wear rates in the anticipated order and gives reproducible results. This test is performed on a Tabor abraser (research model) consisting essentially of a turn table that holds and rotates the test specimen and a pair of rubber-base standardized abrasion wheels that produce wearing action on the specimen. These wheels revolve in opposite directions and slide radially, one to the outside and the other to the inside of the wear path. The resulting area of the wear path covers approximately 1½ sq. in. with a speed of rotation of the specimen of 70 rpm.

The load on the abrasion wheels can be varied by means of sliding weights. A shear-hardness test, which is a measure of the toughness quality of the material, is taken with a special attachment.

A test procedure for this Tabor abraser is outlined and some interesting tables of results are included in this paper.

—J. Palsulich & R. W. Blair. Preprint, *Soc. Automotive Engrs.*, 1946.

Bureau of Standards

Condensed from "Modern Industry"

The Bureau of Standards is not an agency to solve the production and materials problems of any manufacturer, but every industry in the country has benefited by it.

Begun as the Treasury's unofficial office of weights and measures in the early 1830's, the National Bureau of Standards was legalized by Congress in 1900. Its organic act gives it authority only to determine standards and physical constants for use in scientific investigations, engineering, manufacturing, commerce, and by federal and state governments. Yet it undertook fundamental research to improve the value of its standards.

Recently there has been a demand for a new government agency to foster pure research into the physical sciences. There is also a proposal for government laboratories to conduct practical scientific research specifically for the benefit of small businesses. Dr. E. U. Condon, new director of the Bureau, has endorsed this.

Besides government work, the Bureau may, for a fee, aid "any scientific society, educational institution, firm, corporation or individual in the U. S. engaged in manufacturing or other pursuits requiring the use of standards or standard measuring instruments". It will not compete with private laboratories nor will it undertake research to help a manufacturer make a more salable product.

The Bureau will make several types of investigations for non-government agencies. To promote uniform standards, it will compare laboratory standards and instruments with the national government standards. It will make routine tests on materials and devices to determine compliance with specifications, if funds and facilities are available and no commercial testing laboratory has adequate facilities.

Another type is cooperative investigations where outside agencies hire their own scientists to work in and with the Bureau. The project must be one in which the Bureau is interested and wants information and one where the results promise to have wide application.

The research-associate-sponsor must promise to make results available to the government and the public. For these reasons nearly all researches have been supported by trade associations representing an entire industry.

The Bureau will help a manufacturer with a definite problem by sending publications or advice from research but will not help him to design or redesign his product. If Congress decides that this is the concern of the Federal Government, it will have to pass a new law and probably set up a new agency.

Tests of competitive products will be made and the results made available to each manufacturer, but these findings will not tell the specific names of competitors in the test nor permit their use for advertising purposes.

It will prepare simplified-practice specifications, cutting down the numbers of almost identical items on hundreds of products. These studies are initiated only on request and they do not require manufacturers to conform to the recommendations.

A question-answering service for citizens desiring information on scientific and practical subjects is maintained.

—*Modern Industry*, Vol. 2, Mar. 15, 1946, pp. 156-168.

Rate of Loading vs. Strength

Condensed from "Magnesium Review and Abstracts"

Since there was considerable scatter in the results even at a constant rate of loading, this factor had to be considered in the evaluation of the effect of loading. *As Cast Elektron A8.* Variations in the loading rate from 6,720 to 201,600 psi. per min. had a negligible effect on the tensile strength and elongation.

Solution Treated Elektron A8. As the rate of loading increased, the tensile strength

decreased slightly from an average of 38,080 psi. at 4,480 psi. per min. to 36,510 psi. at 168,000 psi. per min. The elongation was not affected. *As Cast Elektron AZ 91.* There was a small drop in the tensile strength from 21,280 to 19,490 psi. as the rate of loading increased from 6,720 to 257,600 psi. per min.

Solution Treated Elektron AZ 91. The results were similar to those obtained with the same alloy as cast. *As Cast Elektron AM 503.* The results were so erratic that no definite conclusions could be reached as to the effect of the rate of loading. *Extruded Elektron AZM.* Within the limits of 4,480 to 168,000 psi. per min., the tensile strength was fairly constant except for a slight increase at the lowest rates. The elongation decreased a little with increased loading rates.

Elektron AM 503 Sheet. Although the elongation remained constant, the tensile strength was 6,500 psi. higher for 336,000 psi. per min. than for 67 psi. per min. *Elektron AM 537 Sheet.* As the loading rate increased from 11,200 to 336,000 psi. per min., the tensile strength definitely increased and the elongation decreased.

Therefore, the cast alloys containing aluminum and manganese and the wrought alloys with aluminum are relatively insensitive to the loading rate. But flat test bars from rolled alloys with manganese or manganese plus cerium are very sensitive to changes in the loading rate.

It is recommended that the following loaded ram speeds be used with all magnesium alloys to ensure comparable results for all alloys: 0.1 to 0.5 in. per min. up to the proof strength and 0.75 to 1.5 in. per min. up to the tensile strength. Likewise, the actual speed should be reported in every case.

—J. L. Walker. *Magnesium Rev. & Abstracts*, Vol. 5, Oct. 1945, pp. 95-107.

The Effect of Grain or Particle Size on X-Ray Reflections

Condensed from "Philosophical Magazine"

In the examination of metallic pieces in powder or solid form, the size of the grains play an important factor in the reflection of the rays and, therefore, on the evaluation of the X-ray pictures. Classifying powders as fine, medium, coarse and very coarse, it was found that fine powders have negligible absorption and the usual theory of reflection is applicable.

For the other grades a correction factor is applied that takes into account the volume of the powder. When applying this theory to solids, as alloys and slags containing two or more coexisting phases, more complicated problems arise than with mixed powders.

In an appendix the calculation of the absorption factors is explained and a table gives the numerical values for particle absorption of spherical crystals.

—G. W. Brindley. *Philosophical Mag.*, Vol. 36, May 1945, pp. 347-369.

BOOK REVIEWS

Materials from the Sea

RAW MATERIALS FROM THE SEA. *By E. F. Armstrong & L. M. Miall. Published by Constructive Publications Ltd., Leicester, England, 1945. Cloth, 5¾ x 8½ in., 164 pages. Price 15s.*

The ocean is a tremendous repository of raw materials, having within it a great share of the more water soluble elements. The authors have brought together in one place the stories of man's attempts and successes in winning chemicals from the sea. The result is a very readable account for the scientist, engineer, or the layman with some general chemical knowledge.

The first chapters review the general facts on the ocean with the theories concerning the relative abundance of the many elements as found, including the very rare such as gold and radium. A chapter on the biochemistry of the ocean details our present ideas on the mutual effects of the elements in the ocean and life in it. Fertilization with nitrates and phosphates may improve the food yield of the sea many fold as illustrated by Scottish experiments.

A chapter on solar evaporation of sea water recounts how this ancient industry still provides several million tons of salt per year. Ninety-nine per cent of the bromine is in the sea so that it is a natural source for our bromine for automotive anti-knock. Processes which enable the separation of the very dilute bromine are described.

Magnesium metal and magnesia refractories are now obtained from the ocean in several locations. The development of these economical processes means that the world will never lack for magnesium raw materials. Seaweed is a source of many products.

Potassium has been recovered directly from sea water in Norway by a precipitation process. The recovery of salts from the Dead Sea and many dried up seas is discussed. The methods of obtaining potable water from the sea and of analyzing the many elements in it complete the book.

Reference to 1945 are included but it seems unfortunate that the authors did not include the monumental volume "The Oceans," 1087 pp., 1942 by Sverup, Johnson & Fleming, which is a mine of information on scientific oceanography.

"Raw Materials From the Sea" is a very interesting volume and is heartily recommended to those with any interest in the chemicals in the sea. It is to be expected that the ocean will become much more important in our economy as we use up our more concentrated resources on land. Processes based on the sea have unlimited raw materials and are available to any nation with coastline.

—L. A. MATHESON

Stress-Corrosion Cracking

SYMPOSIUM ON STRESS-CORROSION CRACKING OF METALS. *Published jointly by American Society for Testing Materials, Philadelphia, and Institute of Metals Div., American Institute of Mining and Metallurgical Engineers, New York, 1945, (sold through A.I.M.E.). Cloth, 6¼ x 9¼ in., 495 pages. Price $5.00 to members of these societies, $7.50 to nonmembers.*

Season cracking of brass has been studied for 30 years, but remains a problem. Cracking under combined stress and corrosion is met with certain strong aluminum and magnesium alloys, in some austenitic chromium-nickel steels, in certain nickel-base alloys, in some gold alloys, in ordinary cold-drawn steel bridge wire, and presumably in boiler plate.

Unrelieved internal stress is probable in such failures, but some specifically but rather mildly corrosive environment is also required. Selecting such a corroding medium for laboratory testing of propensity toward cracking, so that it reflects service conditions, is not simple.

A hundred authors and discussers pooled their experience as to occurrence of failures, their struggles to find applicable laboratory test methods, and their thoughts as to the mechanisms involved. The symposium collects many case histories, through which runs a general pattern of behavior, but with such a degree of individuality in response of a particular alloy to a particular environment that generalization is difficult.

Anyone confronted with the problems of prevention of, or of testing for, stress corrosion cracking will find useful hints, though he may not find a complete answer.

—H. W. GILLETT

Testing and Inspection

X-Ray Equipment. A new 4-page booklet (No. R1023) entitled "X-Ray as a Foundry Control Tool" has been released by the *North American Philips Co., Inc.* (S-51)

Industrial X-Ray Units. General Electric X-Ray Corp. (S-24)

Industrial X-Ray. Kelley-Koett Manufacturing Co., Inc. (S-2)

Testing Machines. Krouse Testing Machines Co. (S-49)

Testing Machines. Tinius Olsen Testing Machine Co. (S-48)

Surface Finish Measurement. Physicists Research Co. (S-46)

Tensile Testing of Fine Wire. Scott Testers, Inc. (S-15)

Supersonic Inspection. Sperry Products, Inc. (S-41)

General Plant Equipment and Supplies

Dust Collectors. An 8-page booklet published by the *Aget-Detroit Co.* describes two models of dust collector equipment. (T-98)

Material Racks. New, self-levelling material racks are described in the *American Machine & Foundry Co.'s* 4-page illustrated bulletin. (T-96)

Gripping Devices. A 4-page leaflet describes the gripping devices developed to pick up industrial loads such as sheets and plates, barrels, etc. *Boyer-Campbell Co.* (T-97)

Shock-Mounts. Machine mountings that dampen vibrations are depicted in an 8-page pamphlet (Bulletin BU-50) published by *Bushings, Inc.* (T-99)

Microfilm. The story of microfilming is told in a 24-page booklet published by *Recordak Corp.* (T-100)

Stainless Steel Valves. Alloy Steel Products Co. (T-73)

Corrosion-Resistant Ceramics. Atlas Mineral Products Co. (T-12)

Industrial Lubricant. Brooks Oil Co. (T-84)

Boring, Milling, Drilling and Tapping Machines. Defiance Machine Works, Inc. (T-50)

Oil Separator. Gale Oil Separator Co., Inc. (T-95)

Foot Switches. General Control Co. (T-92)

Soft Hammers. Gregory Tool & Manufacturing Co. (T-79)

Automatic Clutch. Hardinge Co. (T-76)

Dust Collectors. Ideal Industries, Inc. (T-94)

Conveyors. Lamson Corp. (T-91)

Infra-Red Units. Miskella Infra-Red Co. (T-81)

Electric Meters. Norton Electrical Instrument Co. (T-93)

Dust Collector. Pangborn Corp. (T-20)

Dust Collector. U. S. Hoffman Machinery Corp., Filtration Div. (T-22)

New Materials and Equipment

Metal Coating Process for Corrosion Resistance

The *Glaspray Process Co.*, San Francisco, has developed a surface coating process that offers a unique method of providing protective coatings on metals. The process consists of using the coating metal in powdered form. It is mixed with gas and forced, by means of a "gun", through a flame and onto the surface to be covered. The mechanical operation of the flame preheats the base so that the sprayed coating fuses itself with the steel.

The process is designed to coat metals with zinc, lead, tin, aluminum, brass, bronze, copper, manganese, Monel metal, silicon, nickel, iron and chromium, as well as with glass and plastics.

During the war the process was given extensive use by the Navy to coat ships' tanks with zinc as a protection against corrosion. Tests have indicated that zinc-coated surfaces will maintain an effective protection up to 12 years against salt water corrosion.

Powdered metal sprayed by this gun gives protection against corrosion to metal surfaces.

With the development of this process, new work techniques had to be discovered and perfected. The surfacing application must be handled by thoroughly trained mechanics; and, since it does carry some hazards, a special mask was designed and engineered to protect their faces. They are supplied with pure air in a manner somewhat similar to the method used in deep-sea diving. A suction hose recovers a large part of the grit, and keeps confined areas relatively clean.

One of the promising developments of the process is its application of plastic coatings to metals where acid corrosion is an important factor, such as in the petroleum, chemical, and food-processing industries.

New Cutting Tools, Drills and Accessories

Here are a few of the many cutting tools and attachments being marketed these days by the machine tool industry.

A new line of carbide tipped threading tools (Style T-15) has been added to the line of standard tools of the *Carboloy Co., Inc.*, Detroit. The tools are of the 60-deg. V-nose type, made of Carboloy Grade 78-B, suitable for the threading of steel parts. Shank sizes include ⅜-, ½-, ⅝- and ¾-in. square styles. Shank lengths run from 2½ to 4½ in. Primary clearance at the nose of the tool is 3 deg., with a secondary clearance of 6 deg. This design provides free cutting while insuring ample support for the nose of the tool tip.

A complete line of solid carbide drills is now being manufactured by *Willey's Carbide Tool Co.*, Detroit 1. The drills are particularly suited for drilling cast iron, brass, bronze, magnesium alloys, aluminum and nonmetallic materials. Diameters range from 1/16 to ½ in., and lengths from 2½ to 6 in.

The development of a Carboloy-tipped 3-flute end mill has been announced by The *Nelco Tool Co., Inc.*, Brooklyn 31. This end mill is capable of plunging into solid metal and can also be used for milling plastics. The tool has been designed with ample chip-room for cooler and freer milling. The mill is manufactured for use on all types of alloy steel, cast iron, brass, bronze and plastic material. Sizes range from ⅜- to 2-in. dia.

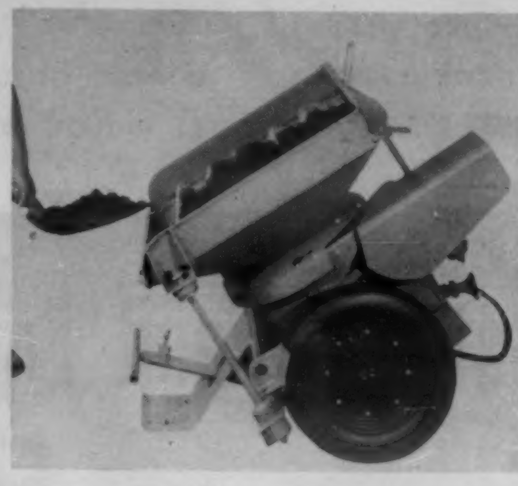
The *Bruno Tools*, Beverly Hills, Calif., has developed an adjustable hole-cutting tool for cutting holes in steel, brass, aluminum and nonmetallics. The cutter cuts holes to any diameter from 1-⅞ to 8 in. and through ¼-in. thickness in steel. This thickness may be doubled if a cut is taken from both sides. The tool is designed to operate in any standard drill press or suitably mounted spindle machine.

Oxford Engineering, Inc., Oxford, Mich., offers a new Swiss type converter designed to make lathes or similar tools into quantity production machines for multi-diameter parts. With this converter any part from a needle point to ½-in. O.D. and from ¼-in. length to 6 ft. can be produced. Any kind of cold-finished stock, including stainless steel, ordinary cold-rolled steel, ordinary cold-rolled brass, aluminum, etc., can be used.

Sandslinger for Foundries

A new portable piece of equipment for the foundry that cleans, cuts, screens, double-aerates and blends sand is being made by The *Beardsley & Piper Co.,* Chicago 39. The machine is really a redesign of the company's Screenarator.

The new model has a re-designed motor of more rugged construction and much simpler design which increases its life and reduces maintenance. The main frame is re-designed and simplified. A brace from the frame fits on the wheels and locks them so as to eliminate movement of the machine while it is in operation.



This portable sandslinger can discharge sand as far as 25 ft.

Another development was relocating the handle of the machine, which is used for transporting it to various locations. This handle is now retractable and is located in such a manner that the machine can be moved forward without going around to the opposite end of the machine. This makes it possible for the operator to move it into the sand pile more readily.

Conditioned sand may be discharged as far as 25 ft. and elevated from 2 to 10 ft., depending upon the operator's requirements.

Portable Brazers

Two new portable brazers have been announced by *Westinghouse Electric Corp.,* Pittsburgh. For general brazing service in joining copper or copper alloy parts which may be brought together between the jaws of brazing tongs, a 10-kva. brazer with air-cooled tongs has been developed.

The single phase, 60-cycle unit weighs 100 lb., is provided with four large caster-type wheels and two handles for quickly moving or carrying any place in the shop or yard. It requires only connection to a 220- or 440-volt source.

Alternating current from an adjustable voltage transformer passes through the tongs and parts to be brazed. Cooling of the unit is effected by natural air draft which enters at the bottom, passes over the brazing transformer, and is expelled through louvered openings at the top.

Also designed for general brazing service is the 20-kva. portable brazer with water-cooled tongs. Enclosed in a circular steel housing, the entire unit is self-contained, having a contactor for energizing or de-energizing the brazing circuit, an adjustable heat brazing transformer, and a water-cooling system for the tong cooling water.

Diameter is kept small (24 in.) so that it can be lowered through hatches, water-tight doors, and manholes. A clamp type entrance bushing is provided on the rear of the brazer for the incoming primary cable. The unit requires only connection to a 220- or 400-volt power source.

The brazing tranformer is air cooled by induced draft. Air is drawn into the brazer through openings under the top cover, is pulled through the transformer and expelled through screened openings in the bottom of the brazer case.

Elongation Testers for Measuring Stiffness of Copper Wire

Two new low-stress elongation testers for measuring the stiffness, or springiness, of large and fine copper wire have been announced by the *General Electric Co.,* Schenectady, N. Y. The large-wire tester measures elongation of wire from 17.9 to 80.9 mils in dia., and the portable fine-wire instrument tests wire from 3.1 to 17.9 mils in dia.

The new testers are useful for determining whether a wire possesses the proper degree of flexibility for use in such winding processes as the manufacture of coils, and make possible a comparison between wires of the same or different sizes on the basis of elongation.

When the large-wire tester is used, the wire is stretched between two clamps, one stationary and one movable, and a unit stress of 15,000 psi. is applied by means of a jack-screw-operated lever arm. Only 30 sec. are required for testing after a few adjustments are made. Elongation is recorded on a large micrometer dial.

When using the fine-wire tester, the wire is clamped between vises located on the ends of two movable arms, and stress is applied by means of weights, which are furnished with the equipment. Adjustments are made with dials on the face of the instrument and with the help of a small neon light which indicates whether the wire sample is under the correct stress. Stretch is indicated on a dial gage.

● The idea of using colors for identification is not new. But using them in a prearranged standard color system to enable a tool operator to distinguish between closely related sizes is new. A color chart, selling for $1, has been developed by the *Larrimore Sales Co.,* P.O. Box 1234, St. Louis. The system enables machine operators to tell instantly by sight what size of drill, reamers, etc. he is picking up, even when the shank of the tool is so chewed up he is unable to read the original stamped size marks.

Phosphate Coating for Rust Prevention

The *American Chemical Paint Co.,* Philadelphia, has available a chemical product known as Duridine 210B (formerly 210B Deoxidine) which cleans and coats metal surfaces, making them rust resistant, and provides a base for durable, protective finishes.

Although this chemical will not remove rust, the hard phosphate coating it provides on metal surfaces prevents rust from developing under paint, and also prevents rust from spreading under paint from metal exposed by deep scratches or other abrasions. Three stage washers suitable for alkali cleaning may be used for the process.

Welding Machine for Fabricating Fenders

The coordinated production of both right hand and left hand fenders at 150 units per hr. is being accomplished by using a welding machine, designed and built by *Progressive Welder Co.,* Detroit 12. The machine has two welding positions—one for left hand and one for right hand fenders. Either position can be operated individually, or both right and left hand fenders can be welded simultaneously. In this machine the dust shields are welded to the 18-gage steel fender.

The machine is so designed as to permit it to be split in two sections and the halves moved to separate locations if desired. Each side has its own welding transformer, current distribution switch, timing circuit and contactor. One hydraulic power unit furnishes welding and clamping pressure to both sides of the duplex machine. Thus, only an additional hydraulic power unit need be supplied to operate the two halves individually.

Three types of welding guns are incorporated in the machine: a standard direct action type, a bell crank type to provide the greater clearance required at several points for easy loading of the parts, and a floating type gun, mounted on the main table, to provide the extreme clearance required to clear the major flanges of the assembly.

View of one section of fender welding machine showing a fender in position to be welded.

Both integral loading fixtures are provided with adjustable positioning arms for accurately locating the headlamp mounts, for a wide range of fender lengths. The accurate location thus obtained and the clamping action provided by the simultaneous impingement of the welding guns on the work results in the production of practically identical assemblies.

New Hydromatic Milling Machines

The *Cincinnati Milling Machine Co.,* Cincinnati 9, announces a line of new hydromatic milling machines for high-speed carbide milling. The new machines are of bed-type construction, with automatic table feed cycles, and infinitely variable hydraulic table feeds.

Standard machines are built in plain and duplex styles, and in twelve sizes, from the models with 24-in. table traverse and 7½ hp., to models with 90-in. table traverse and 30 hp.

The new machines differ from the superseded models in that the tables are 2 in. wider, affording increased work and fixture clamping area. Ways are square gibbed—an important factor of both accuracy and rigidity.

Along with the heavier headstock and spindle carrier castings, the drive is also heavier, with wider faced gears, larger shafts and bearings, and a much heavier spindle. Because of the increased size of the bull gear on the spindle, it provides a fly-wheel effect so desirable in high-speed carbide milling.

A choice of seven ranges of spindle speeds are available. The highest group (cataloged as "3rd High") ranges from 164 to 1225 rpm. for small spindle carriers, 137 to 1000 rpm. for medium spindle carriers, and 110 to 820 rpm. for the large spindle carriers. Eight speeds are available within each range.

New Drilling Compound

A new drilling compound has been developed by Dr. Johan Bjorksten, Chicago industrial research chemist, and is now being manufactured under the trade name Drillyfe by the *Bee Chemical Co.,* Chicago. This drilling fluid was developed to minimize internal friction of the lubricant as well as the chip friction which causes heat formation in drilling operations.

The chemical formulation was built around molecular combinations having a minimum of internal friction, a maximum of lubricity, and the necessary E. P. characteristics to provide for efficient cutting. Ingredients present have a specific affinity to virgin metal surfaces, which provides the chip with an adherent lubricant film. This film retards the tendency of micro chips to wedge between the drill and the bore of the hole, and also speeds the elimination of chips.

Dial Gage Comparator

A new dial comparator model is announced by *Standard Gage Co.*, Poughkeepsie, N. Y. It is suited to a wide variety of uses due to the extensible indicator support arm and the tapped holes in the platen for securing the work. Any dial indicator having a standard AGD lug type back may be used.

By means of a double clamp arrangement the indicator support arm may be slid up or down on the vertical column, swung to any angle in either a horizontal or vertical plane, and moved to place the indicator at the desired distance from the column. Setting is facilitated by a vernier screw.

A friction washer concealed in the swivel prevents the indicator arm from dropping unintentionally when the clamp is loosened for adjustment. Working area of the platen is 6 by 9 in.

Electric Melting Furnace for Aluminum Alloys

Ajax Engineering Corp., Trenton, N. J., recently introduced a 20-kw. induction melting furnace for aluminum alloys, for use as a holding unit in die casting and permanent mold plants. This unit can be placed on the floor anywhere near to the machines without a foundation.

A small self-contained control cubicle is used to control temperature of the melt within a few degrees. The bath is maintained under gentle stirring, thus avoiding segregation of important ingredients.

One of the important features of this induction furnace is the elimination of fluxing. The automatic movement of the bath seems to act in the same way as injected chlorine or nitrogen, the result being that the metal is automatically de-gased.

This unit costs from 8 to 12 cents per hr. to run, depending on the power rates. The only additional cost is the replacement of linings.

This 20-kw. induction melting furnace can be used in die casting and permanent mold plants for melting aluminum alloys.

60-Ton Shop Press

A new shop press of 60 tons capacity is announced by *Rodgers Hydraulic Inc.* of Minneapolis, Minn. Power is supplied by a 2-speed hydraulic hand pump which, in high speed, moves the ram 2-½ in. per pump stroke, giving up to 2,000 lb. pressure in fast travel.

The hydraulic cylinder rests on rollers which ride the flanges of the upper bolster, and may be moved across the entire working width of the press when desired. Ram travel is a full 13 in. at a continuous stroke, due to the long cylinder.

Flexibility of the press is achieved through adjusting the lower bolster by means of a hand crank. Maximum opening between bolsters is 38 in., minimum is 8 in. A special model with an opening range from 8 in. to 48 in. is available. Although working width between the sides is a generous 45 in., long pieces may be handled through the open sides any place above the globe valve and pump.

A variety of general shop operations are performed by the press, such as: pressing, straightening, shearing, bending, clamping, riveting, broaching and assembly work.

Spherical Roller Thrust Bearing

Development of a new type of roller bearing, a spherical roller thrust bearing, is announced by *SKF Industries, Inc.*, Philadelphia. This bearing is said to solve the difficult problem of combining in a single bearing the triple features of high load capacity, speed and low temperature.

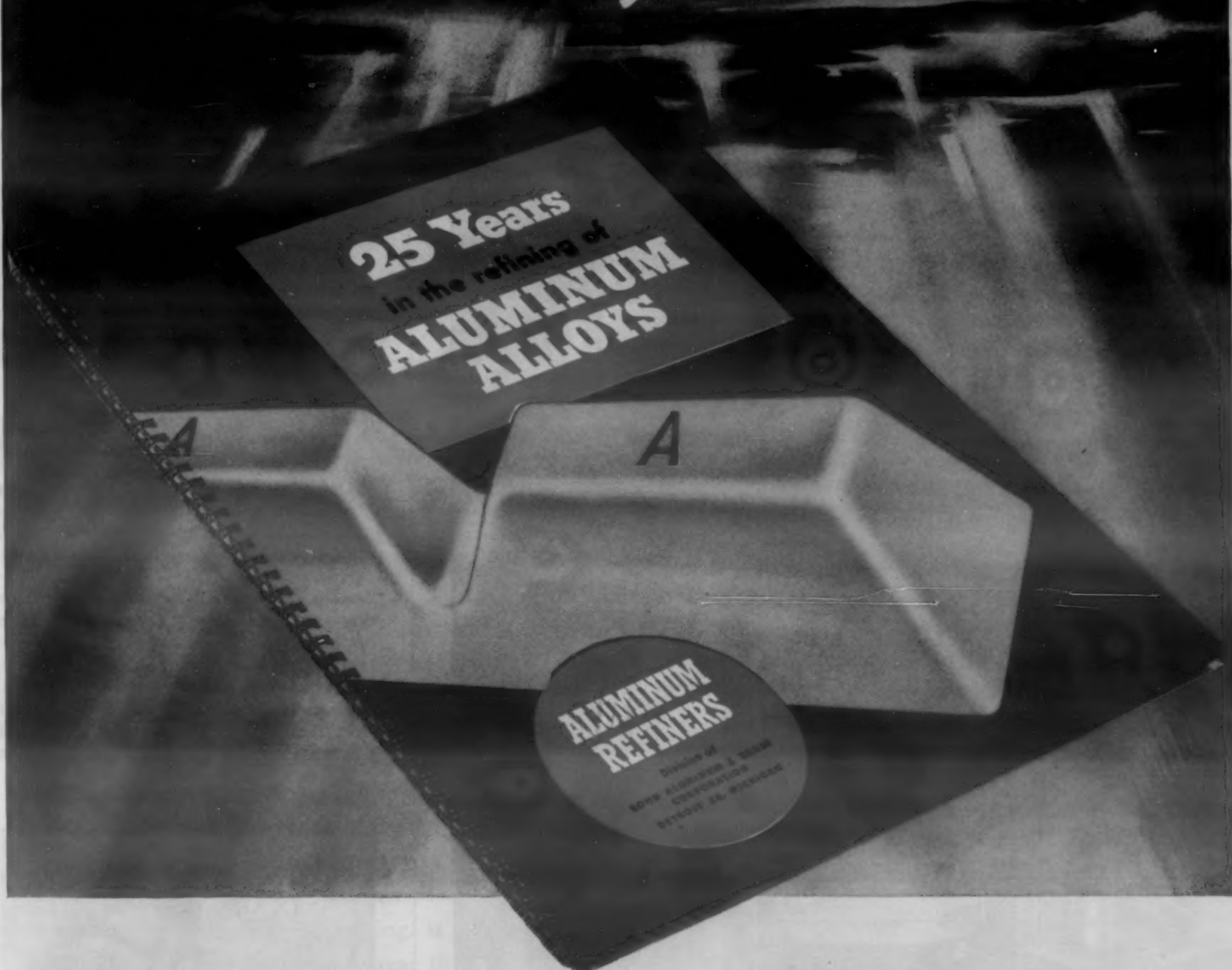
This new bearing, it is expected, will be applied as thrust blocks on marine propeller shafts, on roll necks in steel and aluminum rolling mills, and as thrust mountings for railroad turntables, water turbines, water wheels, oil well swivels, dredge pumps, extrusion machinery for plastics and rubber, and various types of gear drives.

The bearing's self-aligning principle, which compensates for any shaft deflections, distortions or weaves, permits heavy loads to be distributed evenly over all rollers and eliminates danger of overloading. Another feature of the bearing is a cage-retaining sleeve pressed into the bore of the inner ring, making a contained assembly of the rollers, cage and inner ring.

Here's a

REFERENCE AND SPECIFICATION BOOKLET

for daily use!



If you have not as yet received one of these interesting and useful booklets, write us. We will see that you receive one immediately.

Listed for constant reference are specifications of the various aluminum alloys in daily use.

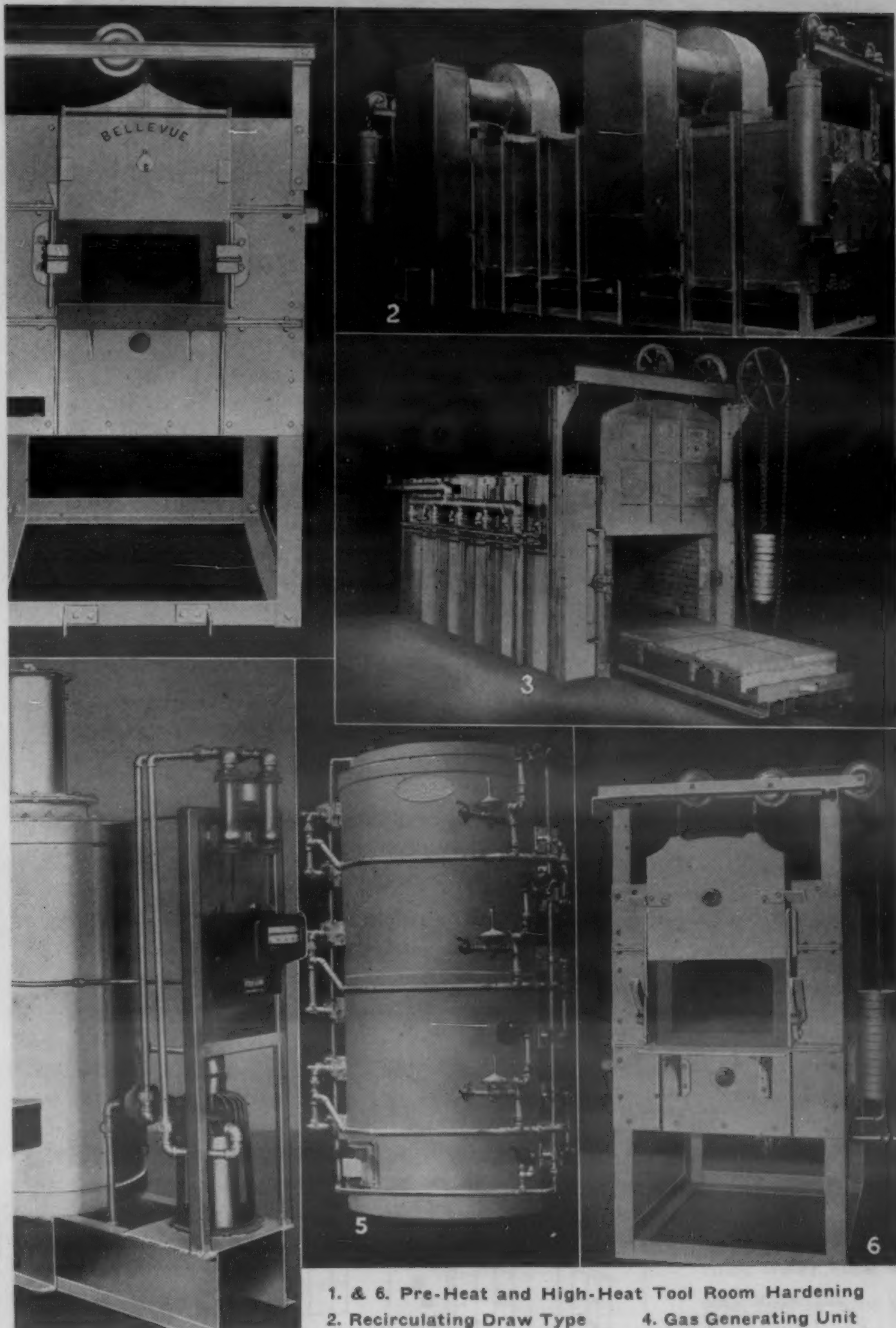
ALUMINUM REFINERS

Division of

BOHN ALUMINUM & BRASS CORPORATION • Detroit 26, Michigan

General Offices, Lafayette Building

MANUFACTURERS OF ALL TYPES AND SHAPES OF CASTING AND DEOXIDIZING ALLOYS



1. & 6. Pre-Heat and High-Heat Tool Room Hardening
2. Recirculating Draw Type
3. Gas-fired Car Type
4. Gas Generating Unit
5. Vertical Muffle Type

New High Pressure Die Casting Machines

Two manufacturers recently announced new developments in their line of high pressure die casting equipment. One of these companies, The *Hydraulic Press Manufacturing Co.*, Mount Gilead, Ohio, has designed die casting machines for casting magnesium, aluminum and copper alloys in which the mold clamping, metal injecting, core pulling and ejecting units are all operated by direct hydraulic means.

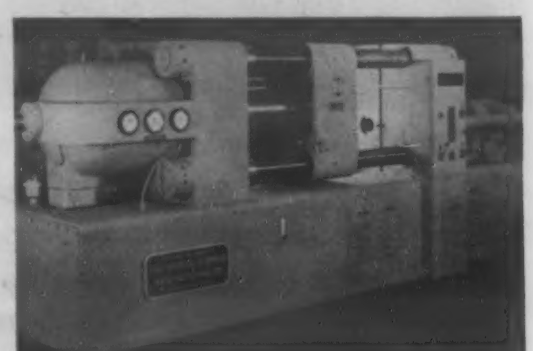
These pressure die casting machines have injection capacities from 12½ to 100 cu. in. per cycle. Injection pressures from 6,000 to 50,000 psi. are available, depending upon plunger dia. Two standard machine models, the 400-A (aluminum) and the 400-M (magnesium), are now being produced.

The basic difference between these two models is the speed of the plunger. On the magnesium machine the plunger is actuated by a nitrogen accumulator or "bottle". This provides injection speeds up to 7,200 in. per min. Due to the fact that the injection speed is adjustable, the magnesium machine can also be used for die casting other alloys.

The standard aluminum machine employs straight-line hydraulics, the injection ram being directly connected to the radial pump. Maximum injection speed of the aluminum machine is 750 in. per min.

Hydropress Inc., New York, has developed a line of six sizes of cold chamber die casting machines. These machines are of horizontal design with vertically arranged injection chambers, full-hydraulic, semi-automatic and electrically controlled.

Since the pouring station is separated from the die, the metal cannot be injected without closing the die. A double action



Mold clamping, metal injecting, core pulling and ejecting units all are operated by direct hydraulic means in this die casting machine.

injection valve for slow injection speed at the beginning, and a booster action, increasing the speed in progress of the injection, insures slow metal filling velocities and high final pressures.

The die casting machines are built according to individual requirements either for water hydraulic or for oil-hydraulic operations for working copper, aluminum, magnesium and zinc alloys. The six models range from 10 to 190 tons injection pressure and have casting volumes, respectively, of 3 cu. in. to 300 cu. in.

Pouring Ladles with Air-Cooled Trunnions

A new line of all-welded ladles has been introduced by *Whiting Corp.*, Harvey, Ill. One of the features of these ladles are the trunnions which are welded to channel-shaped members permitting air circulation. This type of construction eliminates the distortion of trunnion shafts which ordinarily builds up month after month until binding action makes it difficult, and sometimes impossible, to turn ladle to pouring position.

To eliminate other pouring hazards, trunnion bearings, of the self-aligning anti-friction type, are enclosed in shot and dirt proof housing with shot guards provided for additional protection.

The tipping of the ladles has been facilitated by a new style gear bracket which, through self-locking gearing, eliminates backlash. Turning the hand wheel in either direction operates a bellcrank which, in turn, operates a reciprocating type oil pump, forcing a constant flow of clean, fresh oil to bearings and other moving parts.

● A new synthetic rubber paint, known as "Vulcaband," introduced by the *Bray Corp.*, Pasadena, Calif., can be used in the foundry as a protective finish for a wood pattern. The moisture-proof film it puts on the wood permits the pattern to be drawn from the mold without damage.

Multi-Position Pyrometer Controller

The *Wheelco Instruments Co.*, Chicago, Ill., announces a multi-position electronic pyrometer controller. Known as the Multronic Capacitrol, it is designed for applications requiring instantaneous, accurate indication and control of temperature, voltage, current, signalling and similar variables in process industries.

The new instrument provides (1) conventional on-off control at one or two different points, or (2) control of two separate fuel systems on a single pot or other heat-treating type furnace, or (3) automatic positioning control for electric, oil and gas-fired equipment, or (4) on-off control plus automatic fuel shut-off, or (5) multi-signalling at two points or two signals at dual points.

Two "electronic control" circuits (no mechanical contact) operate in harmony with each other, but independently, to control the variables as measured by an indicator (featuring Alnico magnet), providing instantaneous control action.

● The *Richardson-Allen Corp.*, New York 11, announces a line of nine models of variable platers. The models can be supplied as basic units with separate remote control, or as self contained units with meters and stepless variable auto-tranformers.

Dielectric Heater for Plastics

A new electronic heater for dielectric heating of plastic preforms has been announced by the *Industrial Heating Div.* of the *General Electric Co.*, Schenectady, N. Y. It is designed for operation at 40 megacycles, using a water-cooled oscillator tube. This tube, operating at a high frequency and having a generous short-time overload capacity, makes possible the use of an average full-power 5-kw. output during the entire heating cycle. This speeds up the preheating operation without the use of complex control equipment.

After the plastic preforms are placed on the electrode of the oven-like preheater and the cover is closed, the preheat cycle is started by means of a push-button station. The rest of the operation is automatic. The oven cover opens automatically at the end of the preset heating cycle, and the operator then transfers the preforms to the adjacent molding press.

Small enough to fit conveniently between two molding presses, the new heater is able

A view of the electronic heater for dielectric heating of plastic preforms.

to accommodate the alternate operation of the two presses. All controls except push buttons are located behind the locked front door to prevent tampering. The heater is mounted on casters so that it can be readily moved from one location to another.

● The *Jessop Steel Co.*, Washington, Pa., announces a new line of carbide-inserted compacting dies which are being marketed under the trade name of "Malta." The dies are now being furnished in size from ⅛-in. solid drilled dies, guides, and bushings, to 36-in. inserted drawing dies.

Motor Head Production Lathe

The *R. K. LeBlond Machine Tool Co.*, Cincinnati 8, has recently redesigned and is now in production on a new 13-in. motor head rapid production lathe, for light cutting at high speeds.

The two essential elements of the electric motor—stator and rotor—are built integral with the headstock. Instead of the usual gears and belts, the headstock contains a stator bolted to the casting, and a rotor pressed onto the spindle. This motor head operates at 5 hp. at top speed, and is said to run quietly without vibration at speeds as high as 3600 rpm.

A simple electric start-stop box replaces the usual levers and handles, resulting in neater appearance and easier operation. All controls are less than arm's length from the operator, including the new speed-change handle located in the head and leg.

Various attachments such as those used on the manufacturer's standard 13-, 17- and 20-in. production lathes are also available for the new motor head.

● A new Inconel welding electrode for a.c. and d.c. welding of various Inconels is sponsored by the *International Nickel Co.*, 67 Wall St., New York. It is applicable to the chemical and aviation industries and in general metallurgical fields. It is characterized by improved arcing qualities, simplicity of slag removal and ability to make crack-free welds in any thickness. It may be used on straight or reversed polarity.

Rotary Die Grinders

Ideal Commutator Dresser Co., Sycamore, Ill., announces a new pneumatic rotary file and die grinder for tool room and machine shop work. Through the use of a vane type air motor the grinder reaches a speed of 25,000 rpm.

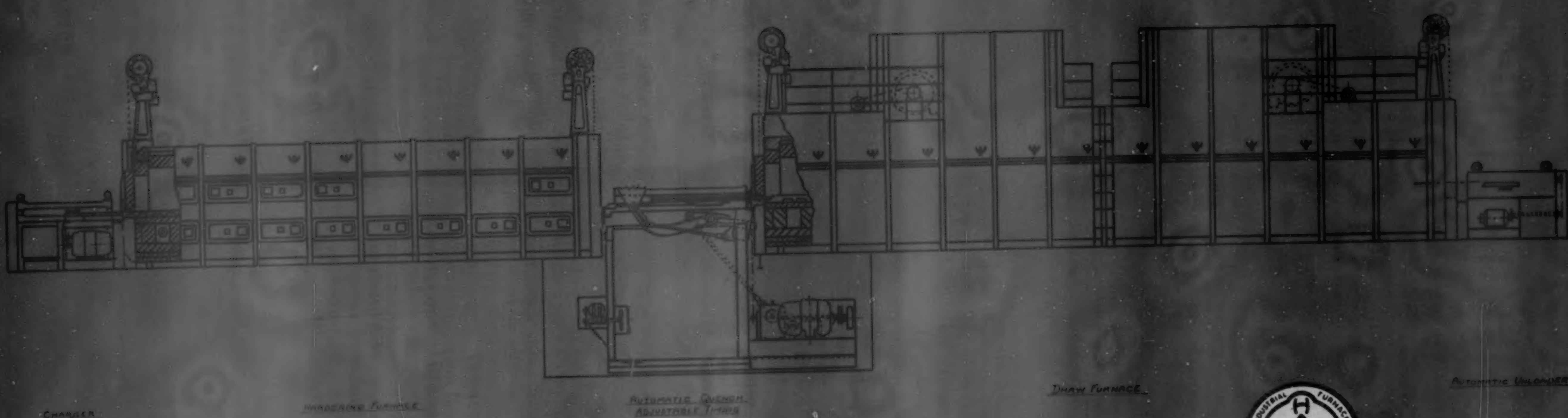
The unit weighs 16 oz., is 6½ in. long and 1½ in. in dia., and is suitable for tool and die grinding work; it can also be used as a tool post grinder.

Wyzenbeck & Staff, Inc., Chicago 22, are producing three high-speed electric grinders that are applicable to a variety of uses in the tool and machine shop, including grinding, burring, filing and polishing work.

The three sizes are made for light, medium and constant duty—one model has a free speed of 16,000 rpm., another 18,000 rpm., and the third 15,000 rpm.

● A new line of supersensitive balancing ways is announced by *Ideal Commutator Dresser Co.*, 1928 Park Ave., Sycamore, Ill. Through the use of "scale type" bearings in the small 10-in. size, sensitivity to 0.007 oz.-in. is possible. Bearings in the 20- and 42-in. size permit balancing accuracy to 0.009 in. The machine balances grinding wheels, fans, pulleys, etc.

Hagan *Automatic* HEAT TREATING FURNACES



HAGAN — INDUSTRIAL FURNACES FOR ALL PURPOSES

TYPICAL LAYOUT OF Hagan Engineered Automatic Heat Treating Unit for large automotive manufacturer.

FEATURES include continuous <u>automatic</u> hardening, quenching and drawing singly or in quantity . . . mechanical reloading after quenching, on carriers . . . ADJUSTABLE TIMING . . . AUTOMATIC UNLOADING . . . all characteristic of <u>Hagan</u> engineering ability to design and build furnaces to fit your specific needs.

GEORGE J. HAGAN COMPANY
PITTSBURGH, PA.

Dry Lubricant for Sawing

The *Monogram Manufacturing Co.* of Los Angeles is marketing a new dry lubricant for use in sawing and drilling operations. The lubricant is made of turpentine, mineral oil, paraffin and other materials.

In a test of this lubricant, an airplane wing assembly constructed of chrome-molybdenum, 4-¾ in. thick cut at the rate of 1 in. every 10 min. A total cut of 65 in. was performed with one blade. A 14-pitch saw was used at an operating speed of 105 ft. per min.

An automatic applicator is used to apply the lubricant; it consists of a square metal holder in either ½-in. or 1-in. sizes with a slot running lengthwise, and is attached to the band saw guard. The slot guides a small weight resting on top of the stick of lubricant which passes between the teeth of the saw to the inside surface assuring adequate lubricant on both sides.

Here is shown a stick of dry lubricant being inserted into an automatic applicator on a band saw used in cutting chrome-molybdenum.

Square sticks are used in the automatic applicator, while the lubricant is available in package form for manual uses.

New Drilling Machine

A new 20-in. drilling machine has just been announced by the *Sibley Machine & Foundry Corp.*, South Bend 23, Ind. The unit is standard with motor drive and belt guard, or, where it is necessary to operate the machine from a line shaft, with tight and loose pulley drive. This machine is especially designed for drilling up to 1¼ in. in cast iron, or the equivalent in other metals.

The machined part of the main column is 5¼ in. in dia. The drill table rotates on an arm which swings on the column to provide maximum working space. Both power and hand feed are furnished. Adjustment is provided for wear between worm and worm gear.

On the motor drive unit, the motor is mounted on a pedestal, supported by a rigid base cast integral with the machine. V-belt is adjustable through hinged motor mounting plate.

ANOTHER DREVER CONTINUOUS FURNACE

FOR HEAT TREATING STAINLESS STEEL TUBING

UNIFORM QUALITY

AUTOMATIC OPERATION

HIGH PRODUCTION

This Drever, Globar Heated, Roller Hearth Furnace includes a spray quench booth, automatic kick-off table, and complete automatic control and operation of temperature and speed. Maximum operating temperature 2100° F.

The roller hearth furnace, pictured above, was recently installed for continuous and batch annealing of stainless steel tubing ¾" and up. Tubing can be charged automatically, heated and spray quenched for annealing of the austenitic types, then automatically discharged to the kick-off table with a minimum amount of effort on the part of the operator. In the treatment of heat treatable alloys the tubing may be charged rapidly to the furnace, stopped in the furnace, oscillated for a definite time, and then automatically discharged to the kick-off table.

This same type furnace can be adapted with atmosphere gas tight construction with purge and cooling chambers for bright annealing and bright normalizing, brazing, sintering and powder metal reduction. The roller hearth lends itself to the heat treatment of a variety of parts, and to the use of trays for carrying small parts through the furnace line.

Drever engineers welcome the opportunity to discuss your plans with you. Your inquiries on this or any other Drever Continuous Furnace will receive our careful attention. Bulletins are available.

EXPERIENCE POINTS TO THE DREVER CO.

750 E. VENANGO ST., PHILA. 34, PENNA.

PRESSURE QUENCHES · CONTINUOUS FURNACE LINES · HEAT TREATING FURNACES

NEW YORK & NEW ENGLAND—GERALD B. DUFF, 68 CLINTON AVE., NEWARK 5, N. J.
W. PENNA., W. N. Y. and OHIO—H. C. BOSTWICK, 3277 KENMORE RD., CLEVELAND 22, OHIO

Mastic Coating for Many Applications

The *Witco Chemical Co.*, 435-M N. Michigan Ave., Chicago, has developed mastic preparations for varying applications. The mastics are bituminous materials that can be applied to metal surfaces with standard spray equipment and can be air-dried to handle in a few minutes. They require no baking, but will withstand baking temperatures.

There are several types of these mastic preparations with varying specifications which make them suitable for differing requirements. One with sound deadening characteristics is used on automobile doors, deck lids, roof panels, etc; another with high abrasion resistance is used under fenders.

These coatings can also be used to seal seams and cracks, prevent rust and corrosion, and supply a fungus-proof coating resistant to acid, alkali, salt spray, ultra-violet light, etc.

● Two new grinders, a vertical grinder and a die grinder, have been put on the market by *Master Tool Co., Inc.*, Keith Bldg., Cleveland 15. The vertical grinder has plenty of power for extra heavy duty grinding and polishing. It works on castings, on seams of plate fabrications, preparing edges for welding, flush grinding of welded surfaces, and heavy surface grinding. The die grinder is good for dies, for small cone grinding on light castings having small fillets, for burring with rotary cutters and files, and for a wide range of polishing.

Synchronous Motor Welder

The *Hobart Brothers Co.*, Troy, Ohio, has produced a synchronous motor welder utilizing an inbuilt separate exciter. The unit is so proportioned that it can be started across the line; it automatically synchronizes itself by the build up of the separate exciter. The starting current on this unit is approximately the same as a conventional induction motor of the same horse power capacity.

It is recommended that this unit be operated to draw leading current at no load so as to compensate for other low power factor loads. Welding loads with their high horse power demand and low duty cycle have long been a problem to public utility companies. This unit with its unity or leading power factor characteristics makes it a power saving load, both from the standpoint of the public utility and customer.

This machine can also be used as an ac generator for the operation of small tools, lathes, grinders, etc. This is done by coupling the shaft to a gasoline or electric motor and the synchronous motor then becomes an ac generator.

Automatic Recorder-Controller

A fully automatic recorder-controller for temperature and pressure has been announced by the *C. J. Tagliabue Div., Portable Products Corp.*, Brooklyn 5. By use of an adjustable cam, timing starts automatically when the temperature reaches the processing point and is terminated at the desired moment. All valves, whether steam, air, water or overflow, are opened and closed as the process may require without manual attention.

A view of the automatic recorder-controller for temperature and pressure.

A red light glows on the controller during the entire steam-heating phase of the process. When heating has been completed and steam has been shut off, the red light is extinguished and a white light appears. After sufficient time for cooling has elapsed, the white light goes out, indicating visibly to the operator that this cycle has been completed.

● A new device that facilitates making of perspective drawing is the *Pomeroy "Stereograph,"* made by the company of that name at 1783 E. 11th St., Cleveland. It produces a perspective view as stereoscopic pairs showing length, width and depth, or a single perspective drawing. It can produce third dimensional graphs, create space curves and show the internal construction of highly complex machines.

Small Air Powered Drill

A new air-powered ½-in. drill has been designed by The *Aro Equipment Corp.*, Bryan, Ohio. The drill is equipped with an auxiliary handle that can be located in any position around the nose of the tool. The handle threads into a shoe located in ring on nose housing.

To locate handle in new position, operator loosens handle with ⅛ counter-clockwise turn, moves to desired position, then locks handle securely by ⅛ clockwise turn.

The new drill is equipped with a safety throttle trigger that allows the operator to start and stop the tools with a minimum of effort, and control their operation under all conditions. Other features include extra large, heavy duty ball bearings which cushion the action of all moving parts and contribute to long life operation.

Metal Dowel

A new type of metal dowel for metal patterns and core boxes has been announced by the *Kindt-Collins Co.*, Cleveland. Known as the Master Sure-Lock Dowel, it has a new type shoulder and taper fit of the body which is reported to keep the dowel anchored tight. The wrench of hardened steel permits firm tightening of the dowels. The dowels are machined from steel, hardened and cadmium-plated to prevent rust.

The sizes available are as follows: Nos. 1, 2, 3 and 4 standard; Nos. 2 and 3 special with extra long pin and body male part. These long-bodied pins can be fitted with nuts for permanent installation. Nos. 2 and 3 special can be inserted with Nos. 2 and 3 standard wrench.

Cemented Carbide File

A new light weight cemented carbide file for filing bronze, brass and hardened steels is announced by *Henry Disston & Sons, Inc.*, Philadelphia. The filing surface of the tool is a carbide insert supplied by *Carboloy Co., Inc.*, Detroit. The insert is 4-in. long by ¾-in. wide and is single cut with 34 teeth per in. on the same angle as standard mill files.

The carbide insert is in one piece. When one face of the insert eventually becomes worn, the carbide insert can be turned over and the opposite face used, doubling the life of the tool. The holder is of aluminum, for light weight.

The new tool has been designed primarily for deburring or chamfering hardened steels which must be operated at speeds of 450 ft. per min. on lathes both engine and turret. It cannot be used for the hand filing of metal. However, it may be used on molded plastics for hand filing of flat or convex surfaces on which it produces a smooth finish and will not clog.

● A testing unit for testing heavy and large work which cannot be readily tested in any of the standard size Rockwell hardness testers has been developed by *Wilson Mechanical Instrument Co., Inc.*, New York. This furnishes a standard testing unit for mounting in whatever design of rigid frame the user builds to meet his testing needs. Large gears, rolls, and other heavy pieces can be tested for hardness in this manner.

Light Weight Fiberglas

A light weight, noncombustible Fiberglas thermal and acoustical insulation material, developed during the war, is announced by *Owens-Corning Fiberglas Corp.*, Toledo, Ohio. The material is composed of glass fibers, with an average diameter 0.00005 in., which are treated with a thermosetting binder and shaped into resilient, flexible, half-inch-thick sheets. Density is 0.6 lb. per cu. ft.

Thermal conductivity of the Fiberglas sheets is 0.26 Btu. per sq. ft., per hr., per in. of thickness, per deg. F temperature difference, when measured at a density of 0.6 lb. per cu. ft., and at a mean temperature of 75 F. Heat capacity is 0.005 Btu. per sq. ft., ½-in. thick, based on nominal density of 0.6 lb. per cu. ft., and a specific heat of 0.20 Btu. per lb. Moisture absorption is less than 1% by weight.

This material used during the war in military aircraft is expected to find applications in the manufacture of buses, trucks, railroad cars, and other items where light weight is of major importance.

● *Pennsylvania Salt Manufacturing Co.*, Philadelphia, has announced a new rust preventing agent for use on ferrous metals before they are painted, enameled or between machine operations. The product, an inorganic salt mixture used in water solution, is designed for protecting metals for short periods, such as after cleaning and prior to painting or enameling. It requires no rinsing before painting.

Strain-Gage Amplifier

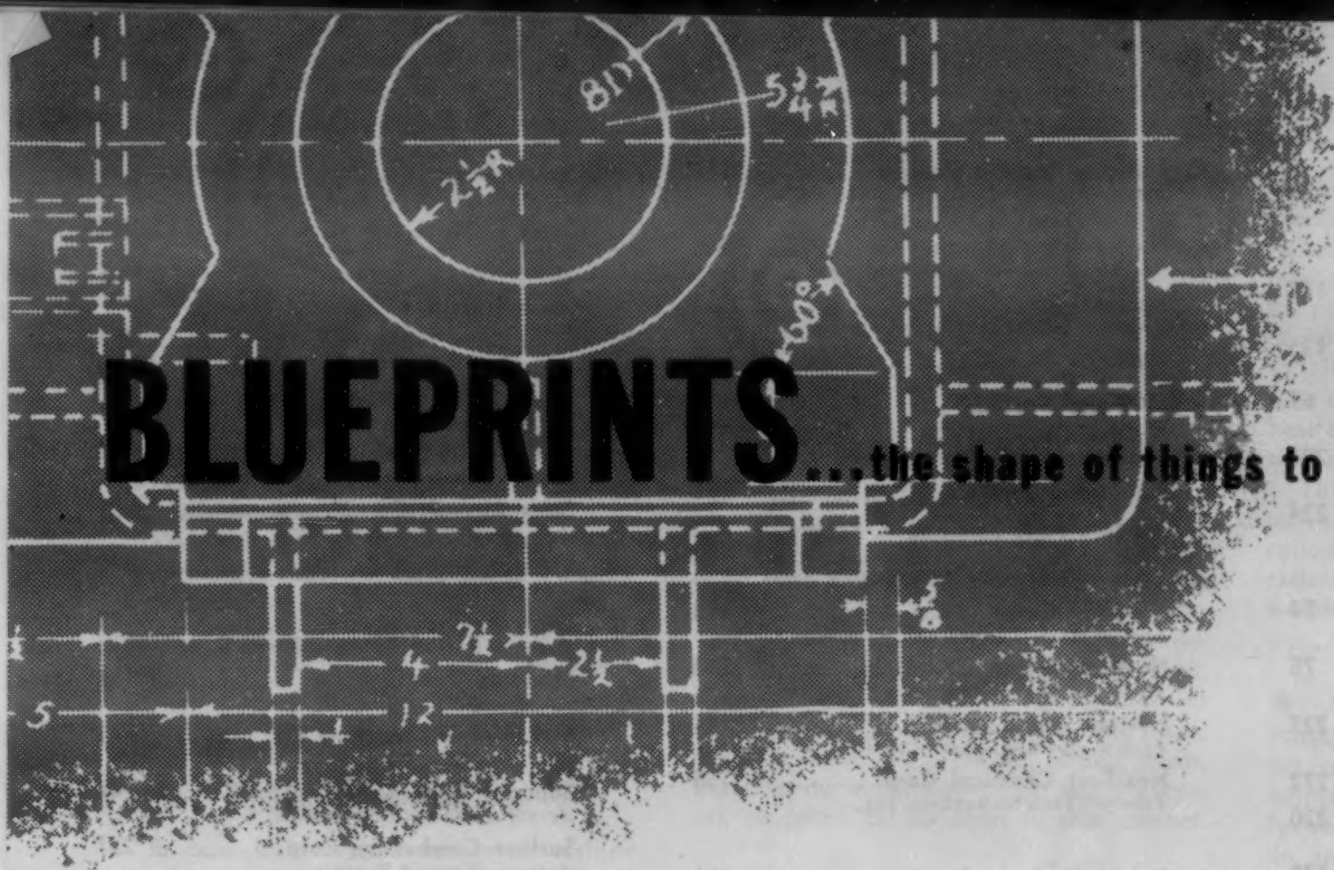
A new strain-gage amplifier has been designed by *General Electric Co.*, Schenectady, N. Y., for use with resistance-wire, electromagnetic and magnetostrictive strain gages for amplifying small electric signals varying in frequencies from 0 to 1000 cycles per sec. The new amplifier is operated in conjunction with either a magnetic oscillograph or a cathode ray oscilloscope.

Small and light in weight, it is suitable for aircraft flight-testing applications when test equipment must be taken aboard a plane, as well as for use in development and testing laboratories and production shops.

Available for use on 115-volts, 60-cycle a.c. or for battery operation at 24 volts, the strain-gage amplifier consists of a 5000-cycle oscillator unit, a power unit, and either two or six identical amplifier units, all mounted in separate chassis in a sturdy case. The amplifier channels are stabilized against line voltage change or variations in tube characteristics, and each can be removed for servicing and inspection.

The instrument and operating controls for each amplifier channel are mounted on the front panel, and include controls providing impedance balance and phase balance for the gages, and instruments showing the output in milliamperes of each channel. Connectors are provided at the back of the unit for connection to the gages and to the indicating or recording instrument.

● *Central Scientific Co.*, Chicago 13, have developed and are manufacturing a new electropolisher for polishing and etching metallurgical specimens. Polished and etched samples can be prepared with this equipment from such substances as low and high carbon steels, plain carbon and stainless steels and most of the cast irons, nickel and nickel alloys, bearing metals, copper, brass, aluminum, zinc and cadmium.



BLUEPRINTS...the shape of things to come

Ceramic Coatings for Hot Use

Ceramic coatings that protected exhaust stacks of military equipment from corrosion will be adapted to peace-time applications. The key material is calcined aluminum oxide added to conventional ceramic materials, the steel being coated inside and out. It is applied in very thin coats, not over 0.002 to 0.003 in. and at 1600 F. It has a dull finish, such as in conventional porcelain enamels. Even when the metal itself bulged slightly from the heat, no damage to the coating accrued. Among applications will be automobile exhausts, stove parts such as inner liners of oil space heaters, burners on gas ranges, coatings for heating furnace tools, and pipe in natural gas fields that must resist hydrogen sulphide.

Features of Near Future Automobile

Automotive engineers believe they see a little more clearly in the crystal ball the automobile of the not far distant future. It will have a supercharged engine, automatic transmission, hydraulic steering, rubber torsion springs and, possibly, bearings of aluminum, with smaller quantities of tin, nickel and silicon. There will be a tendency toward 1000-lb. cars.

Finer Iron Ores

Iron and steel may be made in minutes instead of hours if present researchers succeed in putting their theory into practice. Theoretically, it is best to charge iron ore into blast furnaces as fine powder rather than chunks. But at present such fine powder merely blows out the stack. Present researchers are borrowing from powder metallurgy techniques by "sintering" the ores by which compromise between fines and chunks a satisfactory process may evolve. Theoretically, the smaller the iron particle the more rapid the gassifying action, because of more surface exposed. The aimed-at technique is significant because of the need to use lower grade ores in this country.

Magnesium for Battery Plates

According to dispatches from London, a maker of electric-powered automobiles is using magnesium in the place of lead for battery plates, thus materially lightening the weight of the car. American battery experts are trying to learn whether the British product is in a primary or secondary cell.

Improved Silicones

Apparently the new silicones, heat and acid-resisting plastics, are merely in their infancy as to good qualities and uses. States a chemist of one of the large developing companies: "We have been testing new plastics of the silicone family for some time. Already it has surpassed tests of any other similar material and they can't tell yet when it is going to stop growing better."

Better Welded Ships

Probably never again will as many all-welded ships crack up as during the past war, because of improved designs, better welding technique and better knowledge of the steel. It is learned that semi-killed and killed steel is better for ship plates than rimmed steel. Experts deny that locked-up stresses caused cracking of the ships, but rather faulty root welds and fit-up and wrong type of steel were responsible. Square hatch corners had a notching effect—better round the corners. Future ships will have the bilge-keels scalloped to relieve strain when welded on with one weld. One will hereafter improve ship-fitting to avoid notches causing tri-axial tension.

Stainless Steel Stampings

The use of stainless steel stampings in 1946 will expand 50% over 1941, according to a foremost expert. They will be used extensively in equipment in such industries as food, brewing, paper and pulp, oil refining, dairy, chemical, textile, household cooking utensils and appliances.

Aluminum Heat Transfer Units

Some new principles of heat transfer equipment were developed during the war for airplane use. As a consequence it is possible to make some very efficient units that are extremely light in weight and compact. One takes wafer-thin sheets of aluminum and stamps them to form a series of half tubes on their faces. When two sheets are fastened together by a special brazing process a complete tube arrangement results. Sheet pairs are then assembled in groups so that a series of many tubes are formed and arranged so that air passes through the tubes and over them as well. Moreover the units are made airtight. The original use as an aircraft radiator should see many peace applications in heating and air-conditioning and related enterprises.

Motor Cooled by Fuel

One of the interesting features of the German V-2 bomb was that the alcohol, which eventually served as fuel, was used for cooling prior to its consumption as fuel. Which is by way of introducing a new electric motor to drive a booster fuel pump for a jet-propelled plane. The motor will be mounted in the fuel tank itself and be cooled by the gasoline or kerosene circulating between an outer housing and the frame. Naturally, the motor will be made explosion-proof.

Resistance Coating for Magnesium

A new coating for magnesium to make it abrasion resistant as well as corrosion resistant, that is superior to best chemical coatings, is out of the laboratory stage. It is a heavy oxide coating produced by anodic oxidation in a sodium hydroxide electrolyte followed by sealing in a chromate solution. The coating is hard and smooth and can be made in a uniform thickness as high as 0.0006 in.

Quick Freeze Aluminum Foil

What is described as "sensational" new aluminum foil products are being developed. Particularly interesting will be a heavy foil package in which food can be quick frozen in half the usual time. Perhaps some industrial application! Eh, what?

Die Cast Auto Engines

In an editorial early this year we referred to die cast automobile engines. It can be stated further that aluminum as such die cast material is "in the works", to be formed in one piece on giant and specially designed machines.